

GEOLOGY OF PIOCHE, NEVADA, AND VICINITY

BY
FRED J. PACK

Reprinted from
SCHOOL OF MINES QUARTERLY,
Nos. 3 and 4, Vol. XXVII, April and July, 1906.

PRESS OF
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GEOLOGY OF PIOCHE, NEVADA, AND VICINITY

FRED J. PACK

INTRODUCTION.

During the early seventies Pioche was one of the busiest mining camps of the West. Its period of greatest activity began in 1870 and ended in 1876. Since then the mines have been idle except for a short time near the beginning of the nineties.

The opinion is generally held by those who are but slightly familiar with the district that its deposits have been practically exhausted, and that further efforts to develop them would be attended with complete failure. This impression is doubtless the result of the sudden shutting down of the mines in 1876, and the failure of an attempt to reopen them some fifteen years later.

Very little has been recorded concerning the geology, for the period of mining activity was so brief that interest soon died out, and to-day the camp is almost wholly forgotten.

Mr. Grove Karl Gilbert visited Pioche under the direction of the Wheeler Survey in 1871. He made some observations on the stratigraphic and economic features, and also gathered a number of fossils, but these were later destroyed by fire. His notes are general and give but a very brief outline of the geological conditions. (See Wheeler Survey, Preliminary Report, Exploration in Nevada and Arizona, War Department, 1871, p. 42.)

In 1872 Maj. J. W. Powell, also of the Wheeler Survey, made a brief study of the structural features. He worked out the relation of some of the ore bodies to the stratigraphy, and also to the faults. The results of his investigations are extremely valuable, as, indeed, many of the conditions which he observed are now inaccessible. (U. S. G. S. West of the 100th Meridian, Vol. III., pp. 243, 257-261.)

So far as can be learned Mr. R. W. Raymond, then United States Commissioner of Mining Statistics, was the first to study the district purely from the economic standpoint. He made a trip to Pioche in 1872, and has left on record only a few paragraphs as the result of his investigations. (Mineral Resources West of the Rocky Mountains, 1873, pp. 176-180.)

In 1885 Mr. C. D. Walcott, of the United States Geological Survey, made a rather extended trip through various parts of Nevada. He gave considerable attention to the Cambrian section at Eureka, and later studied the Highland Range a few miles to the west of Pioche. He also made observations in the Pioche Mountains, and discovered, or at least described, a very fossiliferous horizon belonging to the Mid-Cambrian, which he correlated with certain members in the Eureka section. He collected a fauna that had not previously been described. Mr. Walcott's report was the first that in any way aimed to give the details of the stratigraphy, indeed, his is practically the only statement relating thereto. (See U. S. G. S. Bulletin No. 30.)

Mr. J. E. Spurr, of the United States Geological Survey, while on a long trip through southern Nevada in 1899, visited Pioche and made a number of observations in the vicinity of the mines. As far as his conclusions are recorded he confirms the opinions of those who preceded him. He has given some additional notes concerning the Tertiary formations in Meadow Valley to the southward. (See U. S. G. S. Bulletin No. 208.)

Mr. R. W. Raymond has put on record considerable data concerning mine production. From this source the writer has largely drawn for the statistics contained in this article. (See Mineral Resources West of the Rocky Mountains, 1870-1876.)

A great many mining reports have been written on the various properties, but as they were never intended for the public their circulation has been very much limited.

Through the suggestion of Prof. James Furman Kemp the writer undertook the investigation of the Pioche region. We had well in

mind the fact that the district offers a wonderfully fine combination of problems in nearly every branch of geology. There are the ore deposits; the igneous rocks; the sedimentary strata; and the associated fossils beside the many complex structural features.

The writer took the field in the fall of 1905. Many of the old mines were found to be quite inaccessible, and consequently most of the information concerning underground formations, had to be obtained from reports, and from the few mines that could be entered. Since the necessary personal observations were impossible, the details of several of the deposits have been omitted. This is a source of regret, but at present it is unavoidable. The data concerning these formations have been selected with care. Indeed, in most cases they have been verified by observation. Four or five of the mines are still open, and these were studied in considerable detail.

Conditions are almost ideal for surface examination. There is practically no vegetation to conceal the outcrops; the formations all stand out boldly, and the atmosphere is so clear that one can see long distances.

In most cases the outcrops of the metalliferous deposits "weather out," and are thus left standing above the general level of the surface. One occurrence was noted that extended the full length of the claim with scarcely a break.

The larger structural features are worked out with great facility, faults, folds, rolls, fissures and the like are in abundance, but their frequency often involves complex problems.

Mining operations in the fossiliferous horizon aided greatly in the collection of a characteristic fauna.

The igneous dykes were the only formations whose outcrops are not easily followed. They occur largely in the quartzite and limestone, both of which withstand weathering very much more effectively than the dyke itself. Consequently the latter is usually covered with detritus from the other formations.

Subsequent to the first visit the largest part of three months was spent in the office and laboratory at Columbia University working up the field notes, and then a second trip was made to the district. This occurred in February, 1906, and covered a period of ten days. The examinations made during this visit were for the purpose of confirming previous observations, and for settling questions that had arisen during the office and laboratory work in the east.

It is the aim of the writer in the present article to give a fairly complete account of the geology of the Pioche region. The detailed structure of all the ore bodies cannot be discussed as fully as desired, but sufficient information is at hand for general purposes.

The most courteous treatment has been extended by every one to whom I have applied for assistance in the prosecution of this work. While it is quite impossible for me to thank every one who has assisted me, yet I desire to mention Mr. E. P. Gordon and Mr. Ed. Freudenthal for general assistance in the field; Mr. William Lloyd and Mr. J. R. Cook for freedom in their mines and for data placed at my disposal; Mr. J. B. Wheeler for information concerning the old milling processes; the Nevada-Utah Mining & Reduction Company for a surface map of the district, and for other courtesies; and Mr. F. W. Dickle for his many efforts to make my undertaking a pleasant one.

To Professor James Furman Kemp the existence of the present paper is largely due. From the outset I have profited by his cordial advice and kindly criticism. I am also greatly indebted to Professor Amadeus W. Grabau for suggestions throughout the office and laboratory work, especially in connection with the stratigraphic and paleontologic features. Dr. Chas. P. Berkey has given every possible assistance in the petrographic work.

PART I. GENERAL GEOLOGY.

GEOGRAPHY.

Pioche, the center of the Ely Mining District, is situated in Lincoln County, Nevada, near the Utah Line. It is 325 miles southwest of Salt Lake City, and 28 miles north of Caliente, on the San Pedro, Los Angeles, and Salt Lake Railroad. Panaca, a Mormon village, is situated 12 miles to the south in Meadow Valley.

Several years ago a roadbed was made into Pioche, but the rails were never laid. It is understood that the railroad company has stated its willingness to complete this connection just as soon as the production of the district warrants it.

It is a well known fact that the Basin Ranges have a strictly north and south trend. This is so rigidly true that a relief map of the Great Basin looks not unlike an army of caterpillars headed in



FIG. 1. Tertiary deposits near Panaca, in Meadow Valley, twelve miles south of Pioche.



FIG. 2. The town of Pioche. The mines may be seen in the distance. (Looking south-west.)

a common direction. Southeastern Nevada, although just outside the Great Basin, is no exception.

Pioche is situated in a small range of hills extending east and west between Duck Valley on the north and Meadow Valley on the south. The trend of these hills is practically the only exception in southeastern Nevada.

Duck Valley is a broad typical desert valley. There are no canyons and the hills are rounded and rolling. The valley floor is covered by Quaternary wash.

Meadow Valley in its northern parts is likewise broad and flat. To the south it becomes gradually deeper and narrower. Twenty-five miles below Pioche and a short distance above Caliente, it becomes a true box canyon; with nearly vertical rhyolite walls rising on either side for several hundred feet.

During early Tertiary times this valley was converted into a lake through the damming up of its waters by great volcanic outpourings in its southern parts. Several hundred feet of Pliocene beds were deposited in the vicinity of Panaca and southward. Since then the great dam of igneous rock has been cut through, and a large part of the Pliocene beds has been removed. Vestiges of these deposits remain high up on the hill sides, and occasionally a circumdenudated mass still occurs in the valley below. (Plate I, Fig. 1).

The Pioche Range, as it is called, is approximately 15 miles long by 1 mile wide. Its mean trend is about sixty-five degrees west of north. Mt. Ely with an elevation of 7,150 feet is the highest point.

The town of Pioche is situated in a depression of the northern slopes of the range, and about midway between its extremities. According to official survey it is a little less than 6,000 feet above sea level. The hills as a whole are practically one thousand feet higher than the town.

During the early days of active mining the camp had a reported population of nearly ten thousand, while to-day it has scarcely more than three hundred. For a mining camp it is exceptionally clean and attractive. Locust trees planted thirty years ago still survive and give the place a very homelike appearance. (Plate I, fig. 2.)

The general aspect of the country is somewhat rounded. Even the heavy grades and precipitous inclines show evidence of long erosion. The slopes on the south side of the range are more

gentle than on the north. This is especially true in the western half where a fault escarpment marks the northern face.

The surrounding country is extremely dry and desolate. No streams flow from these mountains. A scanty growth of desert sage and scrub cedars comprises the vegetation. Pioche gets its water supply from a spring seven miles to the southwest in the Highland Range. The rainfall is slight and the winters are mild.

STRATIGRAPHY.

DISTRIBUTION AND CHARACTER OF ROCKS.

The accompanying map is designed to give a fairly correct representation of the areal distribution of the formations comprising the Pioche district, yet strict accuracy is by no means claimed for it. The only available map of the district is a topographical reconnaissance sheet based on the notes of the Powell and Wheeler surveys. In working out some of the larger features this was of service, but in detailed examinations it proved entirely inadequate. The writer has been forced to rely largely upon mining maps in determining the geographical distribution of the various formations.

The Pioche Mountains consist of a single anticlinal fold with its axis extending east and west in marked contrast to the general trend of the mountains of the region. The anticline has suffered greatly through faulting and erosion, so that now the various members comprising it are well exposed.

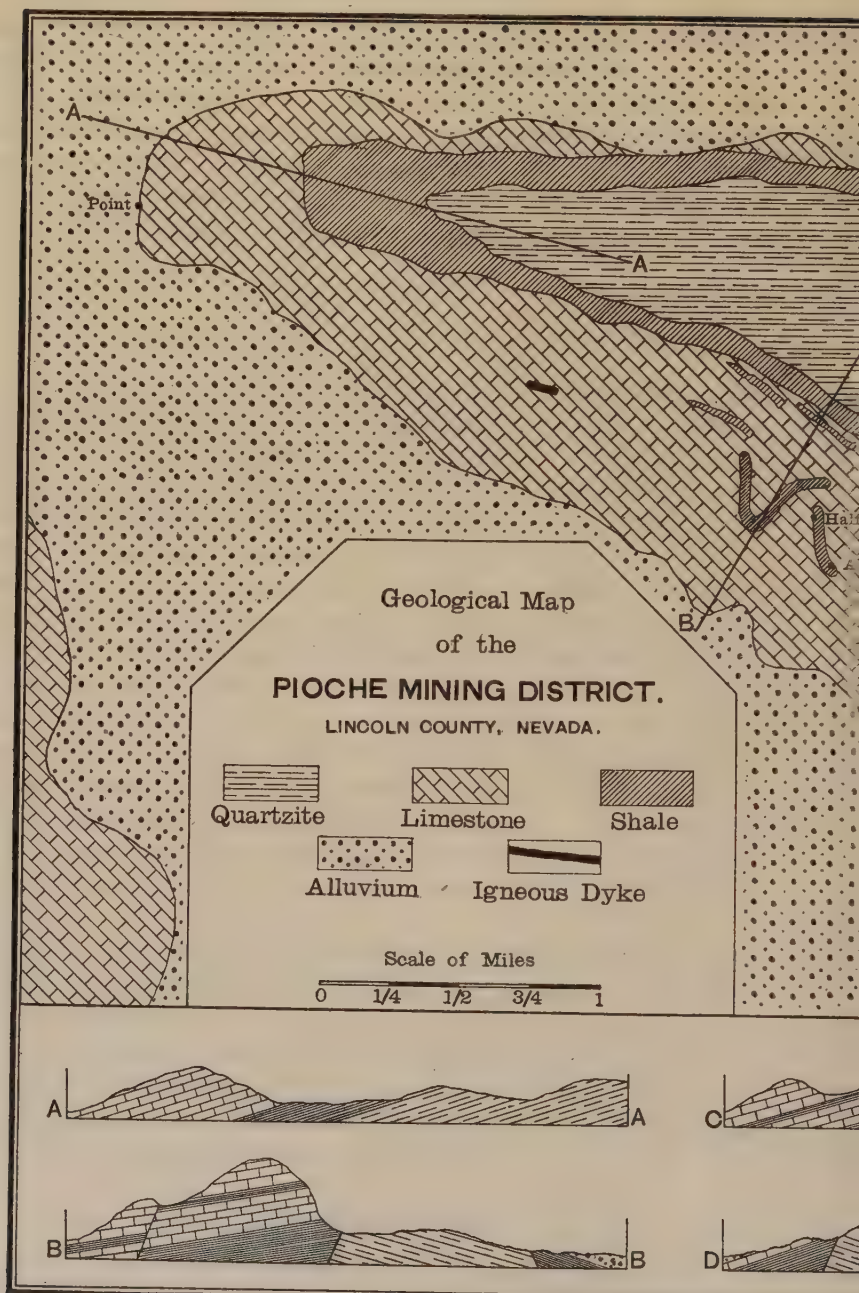
The best sections of the sedimentary formations are to be seen in the western half of those mountains and the mines also are here situated.

The strata comprising the anticline consist of quartzite, shale and limestone. When these formations are projected on a map the shale and limestone are seen to form concentric areas around the core of quartzite. The shale which is superjacent to the core is cut out in a few places by faulting, so that the quartzite comes into direct contact with the still higher limestone. This is the case near Pioche on the north side of the fold.

SEDIMENTARY ROCKS.

Quartzite.

The quartzite is the lowest formation known and comprises the central outcrop throughout the greater part of the anticlinal ex-



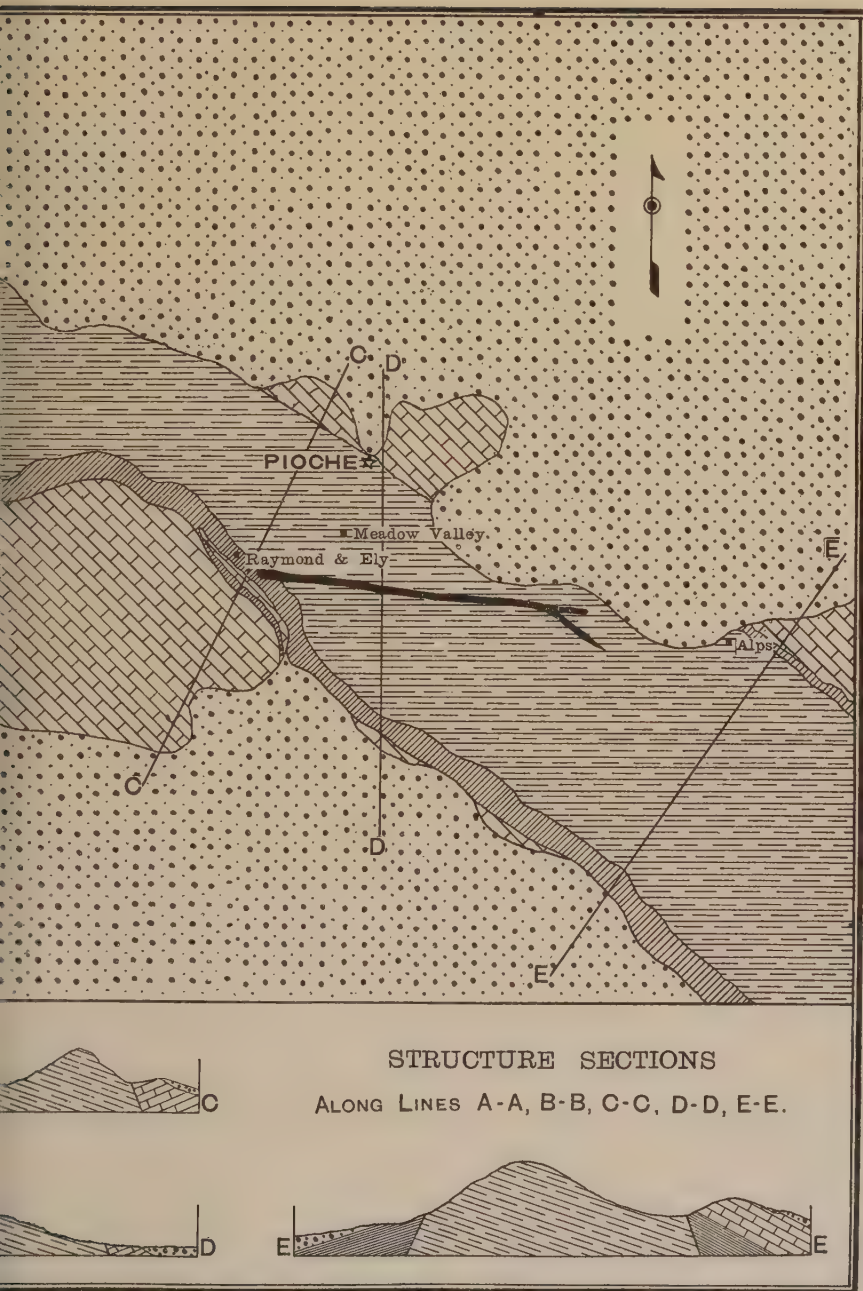




FIG. 1. The Pioche Mountains. (Looking nearly due east.)

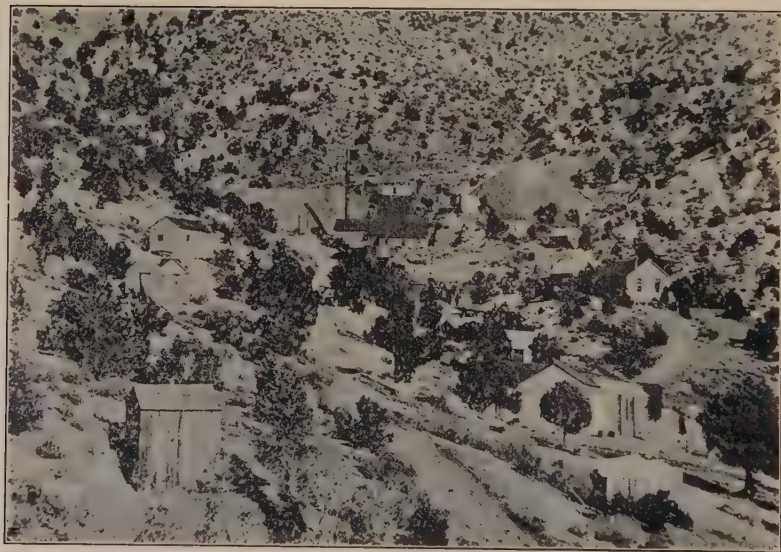


FIG. 2. The Half-moon mine. The dump shown shown in the upper right hand corner affords great quantities of mid-Cambrian fossils.

posure. It has been thrust up between the side members and is, therefore, separated from them on either side by a fault plane.

From Pioche eastward for about two miles it forms the highest topographical features. Both to the east and to the west its altitude gradually becomes subordinate to that of the limestone. This condition is partly explained by reason of the fact that the thrust movement reached its maximum in the vicinity of the Pioche and decreased in both directions.

At the west the southern limestone member forms the central ridge of the range, while at the east this is true of the northern limestone member. The quartzite, although forming the axis of the anticline, does not form the axis of the mountains except for about two miles in the vicinity of Pioche. The two axes diverge from one another with an angle of probably five degrees.

The original bedding planes in the quartzite are largely destroyed, but near Pioche one can determine that the dip is practically fifteen degrees to the north, while elsewhere it varies greatly both in direction and amount. Although in its extreme western extension its contact with the superjacent shales could not be observed, yet there appears to be no fault between them, as they both dip to the west at the same angle.

The quartzite is very compact and massive, and ranges in color from a deep red on the surface to an almost pure white in depth. It is everywhere highly fractured and faulted and, therefore, weathers into sharp and precipitous forms.

Shale.

Superjacent to the quartzite is a layer of shale of varying thickness. It fringes the quartzite on all sides, except for a short distance at the north, where it has been cut out by faulting. In the greater number of its exposures this shale formation retains its original anticlinal inclination. In other words, it dips away from the center in all directions; at the south it dips to the south, at the west to the west, at the north to the north. This regularity has been destroyed in a few places, so that the beds now dip in quite unexpected directions.

In its typical condition the shale may be described as argillaceous. At a few points it has been altered into a fairly good mica schist. This is true in the vicinity of the Raymond and Ely property from which it has been quarried for flagging and building

purposes. It generally occurs as a finely laminated deposit, which when worked breaks along the bedding into thin slabs.

There are two of these shale members; one immediately overlying the quartzite, and the other several hundred feet higher. The second is much thinner than the first, and is much more limited in its distribution. It is best exposed two miles west of Pioche at the Half Moon mine. The general distribution of both shale formations is shown on the accompanying map.

Limestone.

The limestone forms the upper member of the anticline, and is, therefore, situated outside both the shale and the quartzite. It comprises the chief topographic features west of Pioche. In most cases it dips away from the anticlinal core, but in the two hills immediately east of Pioche it dips toward the quartzite.

There are but few traces of the original bedding planes remaining. The whole formation is exceedingly massive and in some places quite silicious. In fact interbedded seams of sandy calcareous shale are not uncommon, but they are very irregular and do not extend over wide areas.

It is at some places divisible into irregular masses (for they can hardly be called beds) of darker and lighter colored limestone. This condition is by no means sufficiently uniform to be useful in marking horizons, and is not, therefore, considered in discussing the stratigraphical position of the various members.

The limestone weathers into rounded masses, which form striking contrasts with the sharp peaks of the quartzite. It is extremely hard and rings under the hammer much the same as an ordinary quartzite.

According to the nomenclature proposed by Professor Grabau the quartzite is a metamorphosed silicarenite; the shale is mostly an agilitite, and the limestone is largely a calcarenite with occasional beds of calcilitite.

Age of the Sedimentary Rocks.

As far back as 1885 Mr. C. D. Walcott visited the Pioche region and correlated the formations with others in the Highland Range which he referred to the Cambrian. He also correlated certain horizons here with the supposed Mid-Cambrian of Mt. Stephen (*Am. Jour. Sci.*, 3d ser., Vol. 36, p. 161), and showed that much of

the fauna occurring at the latter place is identical with that of the Highland Range and Pioche Range.

Mr. Walcott used the *Olenellus* and *Dikellocephalus* zones as a basis for his correlation. He found between these horizons, which are widely separated in Nevada, a large fauna which he decided was approximately equivalent to the *Paradoxides* or Mid-Cambric zone of the east. He, therefore, has described this new fauna as belonging to the Mid-Cambric horizon.

Dr. G. F. Matthew does not concur with Mr. Walcott in this opinion but thinks that the Mt. Stephen fauna is Upper Cambric (*Trans. Roy. Soc. Can.*, 2d ser., vol. 5, sec. 4, p. 39), and would, therefore, argue that the equivalent horizons in Nevada also belong to the same age. He gives a table showing the genera occurring at Mt. Stephen, and also the horizons where related species and genera are found, which according to his arrangement nearly all belong to the Upper Cambric and some even higher.

Dr. Matthew has also advanced the idea in a later paper that the *Olenellus* fauna is not Lower Cambric, but that its proper place is above the *Paradoxides* zone. He would, therefore, have it appear that practically the entire sections at Eureka, Highland Range, and Pioche belong to the Upper Cambric, and that the *Protolenus* and *Paradoxides* zones are probably present below the *Olenellus*, but that they exhibit no faunas in these regions. (*Ibid.*, p. 69.)

There appears, however, to be little room for doubt that the *Olenellus* zone is properly placed below the *Paradoxides* zone, and well within the Lower Cambric. This opinion is held by such high authorities as Walcott (*Am. Jour. Sci.*, 3d ser., vol. 37, p. 374) and Brögger (*Aftrykkur Geol. Foren. i Stockh. Forhan*, No. 101, Bd. 8, 1886, pp. 182-213) and is generally concurred in by all paleontologists.

We do not feel quite so sure, however, that the supposed Mid-Cambric fauna of Nevada and Mt. Stephen are equivalent to the eastern *Paradoxides* fauna, although this view is supported by Walcott and Brögger. The fact that this new fauna stands midway between the *Olenellus* and *Dikellocephalus* zones argues that it is likely Mid-Cambric. Walcott has also shown that many of the forms associated with this new fauna are elsewhere of this age.

The question then as to the exact horizon of many of the Pioche formations is not wholly settled. Years ago Mr. Walcott studied

this matter with extreme care, and has not seen fit to change his opinion by reason of his subsequent investigations. Several new species have been found by the writer, but none of them give any definite clue to the situation. In order to put this matter beyond question other districts must be studied and a wider fauna obtained.

In the present paper we shall hold with Mr. Walcott that the fauna represented in the upper shale member in the Pioche Mountains belongs to the Mid-Cambrian horizon.

Faulting has so disturbed the strata comprising the Pioche anticline that a continuous section cannot be obtained. The quartzite has been thrust up between the flanking members for a distance estimated at fully 1,000 feet. Elsewhere it is not exposed on the surface, except at points several miles to the east of Pioche. Mining operations have shown that it is conformably overlain by alternating beds of shale and shaly quartzite. That is, it passes into superjacent shales through a series of thin transitional beds, which vary greatly in texture and thickness even in short distances.

The thickness of this quartzite formation can hardly be approximated. The Raymond and Ely Mining Company has sunk its works into it for 1,500 feet, and the bottom of the shaft is still within it. We shall, therefore, place the thickness at 1,500 feet, but it is likely very much greater.

Whether any fossils were encountered in passing through the transitional shaly beds has not been recorded, but five or six miles to the eastward at the same horizon a typical *Olenellus* fauna has been found. This marks the Lower Cambrian horizon.

Above the quartzite is some 400 feet of argillaceous shale, which in the immediate vicinity of Pioche has been altered into a fairly typical mica schist. No traces of fossils occur, except near the upper part, where there are a few fragments of *Zacanthoides*.

Superjacent to the shale at Pioche is about 300 feet of massive silicious limestone, which is apparently unfossiliferous. This bed is conformable with the shale below. Its upper limit marks the crest of the hills. Two miles west of Pioche and just beyond Mt. Ely this limestone is fully 600 feet thick, and perhaps much greater, as the base is not revealed.

At the top it passes conformably into a bed of shale which varies greatly in thickness. At the mouth of the Abe Lincoln tunnel, in Chinaman Gulch, it is about four feet thick, while half a mile further west it is fully one hundred feet. This shale seam is



FIG. 1. Section at Pioche.



FIG. 2. Section at the Highland Range.



FIG. 3. Section at Eureka.

everywhere very fossiliferous, and is typically exposed at the Half Moon-Abe Lincoln mining property. The ore body worked by these companies is a bedded deposit occurring within this formation. Mining operations have thrown out large masses of this material and therefore made ideal conditions for collecting fossils.

This is the zone described by Walcott and Brögger as equivalent to the Paradoxides of the east, and correlated by them with the Prospect Mountain limestone and the Mt. Stephen formations. It is separated from the Olenellus fauna by a distance of 1,000 feet at Pioche, by 500 feet at Eureka, and by 1,100 feet at Highland Range. At Eureka the Dikellocephalus zone is 2,500 feet higher. This formation is, therefore, well nigh midway between the upper (Dikellocephalous) and lower (Olenellus) zones, and could very naturally belong to the Mid-Cambric.

At Mt. Ely fully 800 feet of massive compact silicious limestone occurs above this shale member. The same thing is shown in the Highland Range section, except that there the limestone has a thickness of 3,000 feet. It is unfossiliferous in both localities. Mr. Walcott thinks that the summit of this formation as shown in the Highland Range marks the upper limit of the Cambric section.

The accompanying figures show the relative thickness of the Cambric sections at Pioche, Highland Range and Eureka.

IGNEOUS ROCKS.

The Yuba Dyke.

It appears that the early miners attached but very little importance to the presence of the igneous dyke which cut through the center of the mining district. The writer has failed to find any allusion to it in the reports of the old companies, but now it is well known that prospecting is quite unprofitable at any great distance from it.

The Yuba Dyke is situated far up the hillside south of Pioche. It strikes magnetic east and west, and dips to the south at various angles, averaging practically eighty degrees. It varies in thickness from ten to one hundred feet, averaging about seventy-five. In the vicinity of the mines it outcrops almost exclusively in the quartzite, a fact which suggests the thought that its introduction may have taken place prior to the deposition of the superjacent shale. This inference, however, is not correct as the dyke enters the shale for a distance of nearly three hundred feet.

This igneous intrusion was not displaced by the anticlinal faulting which thrust the quartzite up into contact with the shale and limestone, and was, therefore, introduced subsequently to the anticlinal movement and the disturbances that immediately followed.

It emerges from the shale just above the Lightner shaft, and extends in an easterly direction up and over the north slope of Treasure Hill. It then passes down through the gulch at the east, rises to a point near the west end of the Boss claim and then divides. The north branch continues in the strike of the main dyke; the other assumes a direction about sixty-five degrees east of south and extends over the hill toward the old Daly East property. It does not continue far until it is lost; the farther it is followed the smaller it becomes, a fact which indicates that it forms but a small offshoot from the principal intrusion. The north branch also disappears a few hundred feet beyond the point of bifurcation. It strikes in the exact direction of the Alps mine, which is situated nearly one mile away. A continuation of the dyke was encountered at the three-hundred-foot level of this mine, although there are no igneous outcrops for several thousand feet in any direction. The lithological character of the material as well as the strike dip, and width is almost the same as that at Pioche.

The writer made several attempts to trace the Yuba Dyke through the limestone region to the west of the mines, but failed to find it, except as represented by a few isolated outcrops. Just south of the Lightner shaft it strikes up the hill toward the upper water tank, but it pitches into the shale three or four hundred feet east of that point. The next place at which it was observed was in a tunnel at the Abe Lincoln mine nearly two miles to the west. It does not outcrop at this point, but was accidentally encountered by the miners at a vertical depth of one hundred and fifty feet. The dyke material is involved in a displacement which has apparently brought it from below.

About one mile farther to the west and near what is called the "low divide" its outcrop is observed for the first time in the limestone. For about one mile beyond this point it is covered by wash, and then it comes to the surface intermittently for another half mile. It is lost again for a short distance and then outcrops continuously for three or four miles to Stampede Pass beyond which no attempt has been made to follow it.

These isolated exposures are all situated in the projected strike of the dyke at Pioche, a fact which indicates that this igneous body extends throughout the entire distance, but that it does not come to the surface except at a few points. Microscopic examination of samples collected at each of these places shows that the material is all of the same general nature. It appears, therefore, that the Yuba Dyke extends from Stampede Pass in the west to the Alps mine in the east, covering a distance of fully ten miles.

The rock comprising the intrusion is a fairly typical rhyolitic porphyry. The feldspars are highly altered; in fact the only original mineral remaining is the quartz, which gives the material the appearance of a quartz porphyry. The petrography of this intrusion is discussed at greater length in another part of this paper.

At first thought it may appear strange that the dyke at Pioche should be confined almost wholly to the quartzite. Two factors are largely accountable for this condition, first, that the quartzite is now denuded of the higher formations, under which at one time the dyke was likely buried, and second, that the quartzite is much more easily fractured than either the shale or the limestone, and, therefore, offered less resistance to the intrusion of the igneous mass. In other words, the magma penetrated farther into the easily fissured quartzite than it did into the refractory shale and limestone.

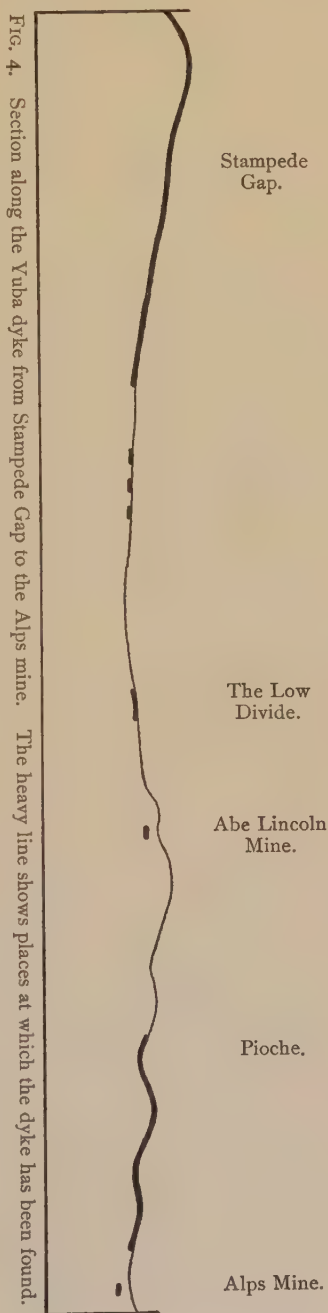
It is now well understood that the force of an igneous intrusion may be spent before the surface is reached. In consequence of this loss of energy many dykes never outcrop. This condition is frequently revealed in mining operations. The writer knows of several instances in which dykes were encountered at various depths, while on the surface there is no indication whatever of their existence. During its dying stages such an intrusion follows the strata offering the least resistance, but when in its prime it cuts through all formations alike. This differential selection is well illustrated in Stampede Gap. The dyke outcrops in the limestone and may be followed with little difficulty. At one point it pitches down under a cherty mass and reappears about three hundred feet farther on. The avoided mass is topographically lower than the rock in which the intrusion occurs.

At the extreme west in Stampede Gap the dyke outcrops strongly and continuously for fully three miles. To the eastward

for nearly the same distance it comes to the surface intermittently, and then disappears under the limestone capping near the "low divide." At the Abe Lincoln mine, one mile further to the east, it is found at a depth of more than one hundred feet, but still it occurs in the limestone. The first outcrop at Pioche does not reach this number, but comes only part way through the subjacent shale. East of this point it is confined to the still lower quartzite; further to the eastward it pitches into this formation and disappears from the surface. At the Alps mine its uppermost part is three hundred feet below the surface.

The dyke, therefore, does not outcrop, except at a few points where it has probably been exposed by erosion. It should further be noted that from west to east the top of this intrusion is limited by succeeding lower strata. At Stampede Pass it penetrates the Upper Cambrian, while at the Alps mine it is lost in the Lower Cambrian.

As before stated the dyke material is highly altered; none of the original minerals remain except the quartz. This is true of samples taken at a depth of fifteen hundred feet in the Raymond and Ely mine. The rock at the Abe Lincoln tunnel is the only exception; here it is fairly well preserved. The crystals are all large, a feature that implies slow cooling, which in this case must have occurred at a considerable depth. The well developed flow-



age structure shows that movement must have taken place after the mass had become crystallized.

It has been shown elsewhere that the movement which resulted in the elevation of the Pioche anticline occurred long before the introduction of the dike. It now appears that the dike is much older than the present topographic features. These facts strengthen the conclusion concerning the remote origin of the Pioche anticline.

STRUCTURE.

As stated elsewhere in this paper, the Pioche Mountains are 15 miles long by 1 mile wide, and trend in a direction about 65 degrees west of north. They are composed of a highly fissured and faulted anticlinal fold, the axis of which does not coincide with the axis of the range, except for a short distance near the central part of the uplift.

In the vicinity of Pioche the quartzite core has been thrust up between the flanking members for fully 1,000 feet, so that it is now separated from the shale and limestone on either side by a fault plane. These planes of displacement are parallel to each other and strike within a few degrees of the mountain axis.

The north one is well exposed near the court house, and extends southeastward through the lower part of the town and up a small gulch toward the old Pioche mine, and then across the flat in the direction of the Alps mine. The dip of this fault is about 70 degrees to the north as shown by an incline sunk upon it at the Bamberger property in the east side of the town.

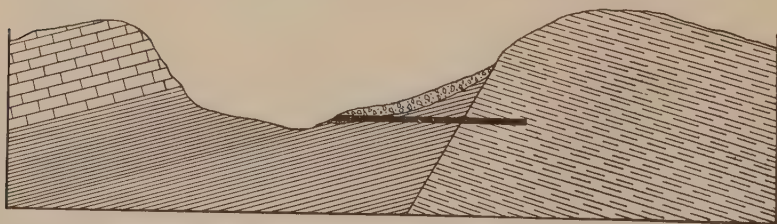


FIG. 5. Section along an old tunnel across the divide from the Williams mine.
(Showing fault plane between the quartzite and the shale.)

The other parallel fault is well shown by an escarpment on the southwestern slopes of Treasure Hill immediately south of the town. Its southeastern extension from here has not been traced, but to the northwest it strikes through the low gap, passes the Lightner shaft to the right, extends across the gulch and through

the low pass at the northwest of the Raymond and Ely ground. Its dip is to the southwest about 60 degrees. This is well shown in an old tunnel just across the divide from the Williams mine. The tunnel begins in a loose quartzite talus and after passing through seventy-five feet of this material it enters the shale, which has been protected from erosion by the overlying talus. It continues in the shale for one hundred and eighty-five feet, at which point it crosses the fault plane and passes into the quartzite. This is shown in the accompanying figure.

Another interesting feature is herewith shown. The fault plane is without doubt primarily responsible for the existence of the low divide shown at the left, the original position of which was immediately above the plane of displacement. As the formations were cut down differential weathering carried it farther and farther to the west, so that now the fault plane is fully three hundred feet to the right of the pass and a considerable distance above it.

It may be thought that this crowding toward the shale and limestone is wholly due to the greater resistance to erosion offered by the quartzite. This is without doubt true of the shale, and especially so in this case, as the ends of the beds are exposed to the weathering. And, indeed, the limestone has also retreated, but largely because of the undermining action of the decaying shale, as proved by the almost vertical cliff of limestone which faces the gulch. The limestone is exceedingly hard and vitreous, and withstands weathering almost, if not quite, as well as the quartzite.

The structure of the anticline is further complicated in the vicinity of Pioche by the existence of a number of cross faults, one of which displaces the Raymond and Ely-Meadow Valley fissure vein about half way between the Lightner shaft and Meadow Valley shaft No. 3. It is suggested by Howell and Spurr that a southwest-northeast fault is the cause of the gulch in which Pioche is situated.

It should also be noted that the anticline pitches downward at its western extremity and abuts against the outlyers of the Highland Range. As might be expected under such conditions cross wrinkling has occurred, resulting not infrequently in transverse faults. Immediately west of Mt. Ely one of these has resulted in a displacement of fully four hundred feet. This is best shown in the Half Moon gulch on the south side of the mountains.

The stratum most easily traced is the fossiliferous shale, which carries a bedded deposit of ore. The dumps from mining pits have made great quantities available. One can stand at a considerable distance and trace it from the west past the Himon mine and around the hillside to the old Chisholm workings. A few hundred feet to the east the shale suddenly curves downward,

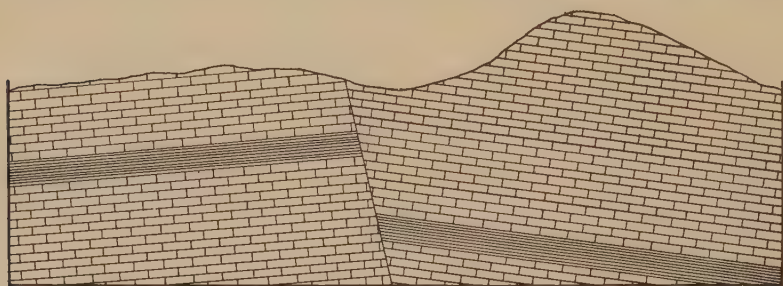


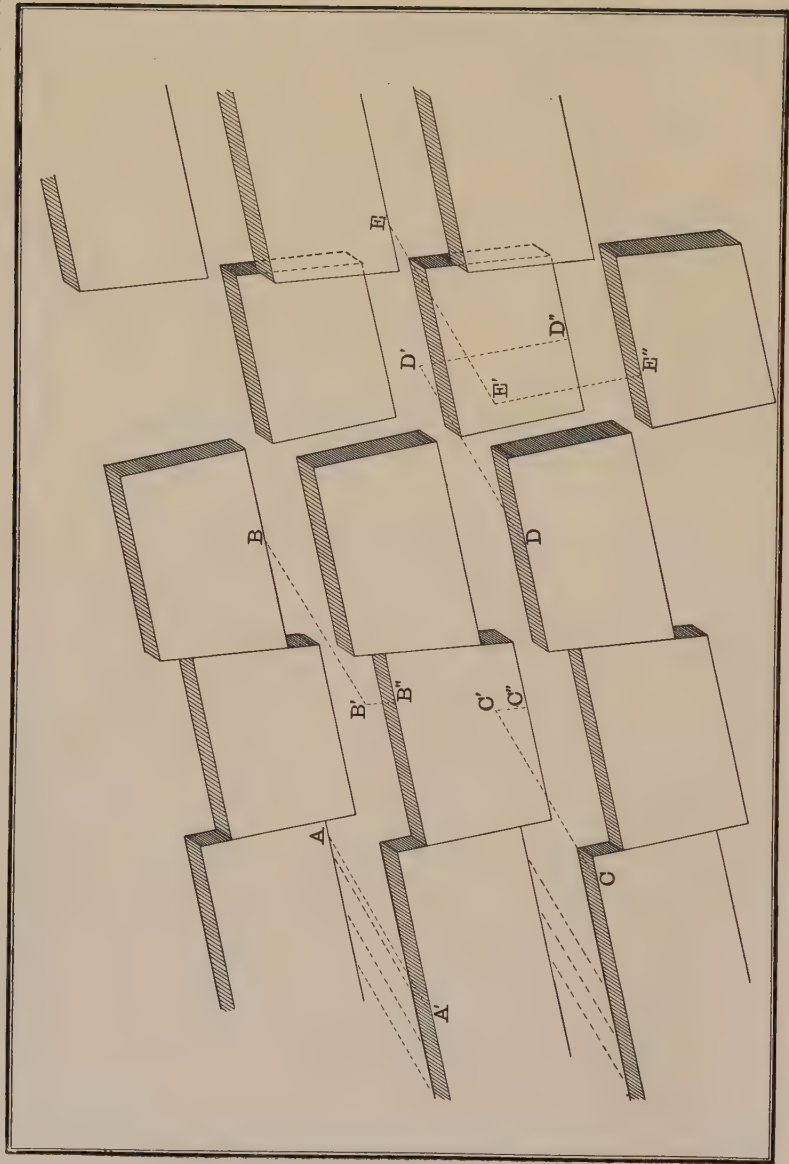
FIG. 6. Section east and west through Mt. Ely, showing the elevated position of the downthrown block.

thins out and disappears. It continues four hundred feet lower on the property of the Half Moon Mining Company. It then passes around the hill to the east and is lost under Mt. Ely. The fault dips to the east about 75 degrees and is readily detected even at a distance.

A very interesting case of faulting occurs at the Mendha mine about six miles west of Pioche. The country rock of the immediate neighborhood is limestone of the Cambic age, and correlated with the upper members of the Pioche anticline. None of the shale and quartzite formations are revealed.

It should be remembered that the Highland Range at the west extends in a north and south direction, and that the Pioche anticline at the east joins this range at approximately right angles. A number of minor crumplings occur where these two ranges meet, one of which extends across the Mendha mining property in a direction 15 degrees east of south. The strata of this uplift dip in a direction 75 degrees west of south at an angle of 30 degrees. An igneous dyke traverses the anticline parallel to its trend and near its apex.

The Mendha fissure vein lies within the western members of the uplift and strikes east and west, making an angle of 75 degrees with the axis of the anticline and 15 degrees with the direction of



Diagrammatic illustration of the faulted condition of the Mendha fissure vein.

the dip of the beds. This point was of importance in working out other structural features. The deposit is a true fissure vein, varying from one to six feet in width, and is quite continuous.

The vein was formed before the folding began. As this movement progressed slipping occurred between the component beds and displaced the ore deposit about 50 feet.

The mine workings thus far show the presence of two of these fault planes. As noted elsewhere they are both of the reversed type. This displacement has brought about the condition that the lower workings of the mine are farther south than those nearer the surface, although the vein dips to the north.

A secondary mineralization followed this faulting, and resulted in the deposition of a highly silicious ore-bearing material along the bedding planes.

Complicated as these conditions may appear they were made more so by the occurrence of another series of faults cutting the fissure vein at right angles. The country was thus cut into blocks, every other one of which was thrown down and the intervening one up. This gave the mine operators endless trouble, as no general rule of interpretation appeared to apply.

It may be stated, then, that the fissuring and faulting occurred in the following order: First, the east and west fissuring which culminated in the formation of the Mendha vein; second, the slipping between the beds, during the anticlinal movement, which resulted in the displacement of the fissure vein and in the secondary mineralization; and third, the cross fissuring and faulting, which displaced the two series of deposits already existing.

The accompanying plate illustrates in a diagrammatic way the faulting just described. The dotted lines indicate the direction of the movement. The intricate condition is the result of but two series of displacements, the first of which carried *A* to *A'*. After the first occurred the vein may be considered as consisting of parallel parts separated both laterally and vertically. The second slipping broke up this regular arrangement and produced the condition shown in the plate. The first faulting

carried *A* to *A'*,

“ *B* to *B'*, and the second *B'* to *B''*,

“ *C* to *C'*, “ “ “ *C'* to *C''*,

“ *D* to *D'*, “ “ “ *D'* to *D''*,

“ *E* to *E'*, “ “ “ *E'* to *E''*.

Another interesting case of the relation of an ore body to the structural features occurs at the western extremity of the anticline. Some time ago a vein was discovered at this point and later it was developed to a depth of nearly one hundred feet; the property appeared to be a promising one and consequently several "extensions" were located. The vein outcropped for a short distance only, but the new claims were located with almost mathematical precision along the direct path of its strike. The locators were thus carried beyond any surface indications and into a gravel-covered area. They were confident that the ore body could be found and decided to sink a shaft through the wash to the bedrock; then, if necessary, to run crosscuts to locate the ledge. When the writer examined the property the shaft had reached a depth of 80 feet; the bottom of the workings were still in the gravel and indications pointed to the conclusion that bedrock was still much deeper. The outcrop was studied with care, as was also the vein in the workings of the original locators. The deposit occurred between limestone beds and consequently dipped with the formations. Surface indications showed that the limestone formed part of the Pioche anticline, which was known to pitch downward at its west end; and, further, that the limestone outcrops did not strike in a straight line, but rather in a curve. Thus it follows that the ore body deposited between the beds would swing round with the outcrops of the anticline. The conditions are shown in Fig. 7.

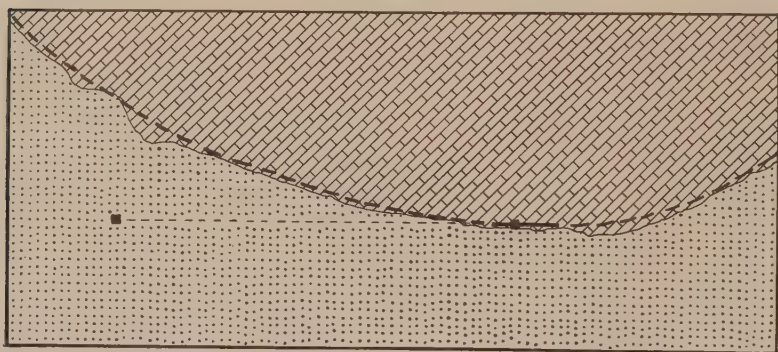


FIG. 7. Point mine and immediate vicinity. (Showing the curved nature of the outcrop.)

Although the new locators were situated in the direct strike of the vein as indicated by the short outcrop, yet they were several hun-

dred feet to one side of the ore body, or at least from its normal position in the limestone.

RELATION OF THE STRUCTURAL FEATURES TO THE TOPOGRAPHY.

The faults of the region bear a most remarkable relationship to the topography. Under ordinary conditions the upthrown block of a faulted area is left in higher relief than the depressed block. Erosion, however, would eventually reduce both to a common level, but in many instances in the Pioche Mountains this weathering process has been carried further, so that now the *downthrown* blocks form the *highest* points. The process is well illustrated in the faulted area at the Half Moon mine (Fig. 6). Mt. Ely which is just above the mine is the highest point in the range, and yet it marks the position of a block thrown down, a relationship illustrated in the accompanying figure. A similar condition exists, moreover, in the hill on the west side of the Half Moon gulch. The fault is normal and strikes nearly east and west. It dips to the south and the throw is about three hundred feet. Nevertheless, the downthrown block now forms an escarpment fifty feet high. The direction of displacement may be traced by means of the fossiliferous shale and adjacent limestones.

Another illustration of this condition is shown about three miles south of Pioche at the Gladstone property, where a block of quartzite has been thrust up into the limestone, and, notwithstanding its elevated position, it marks a low area in the topography of the region.

Just across the divide south of Pioche several smaller faults show the same thing. The limestone which has been thrown down into contact with the quartzite now stands in relief.

The general configuration of the Pioche anticline reveals the same condition. The quartzite core has been faulted upward one thousand feet, and yet, except for about two miles, its elevation is less than that of the flanking limestone. It is true that the throw of the displacement decreases both toward the east and the west, but it does not reach zero, except perhaps at the extreme eastern and western quartzite exposures. West of Pioche the south limestone member rises nearly one thousand feet above the *upthrown* quartzite.

The condition means this at least: the great thickness of limestone and shale once superimposed on the quartzite, and now but

partly represented by the flanking members, has all been removed, and in addition to this the quartzite itself has been eroded, but to what extent cannot be stated with any degree of accuracy. Thus, at least two thousand feet of limestone and shale have been removed from the upthrown central core while the flanking members have actually weathered into relief.

Perhaps a partial explanation lies in the fact that during the process of folding the greatest stress was brought to bear along the anticlinal axis, a part which will, therefore, offer less resistance to erosion than the flanking members. While this suggestion appears possible in regard to the mountains as a whole, yet it does not apply to the cases where the faulting is not accompanied by folding. It may be that local conditions such as rock texture, etc., are partly responsible, but inasmuch as it is quite the exception to find a case in which the upthrown block stands in relief above the depressed one, it appears that there is yet something unexplained. This will be discussed at greater length in considering the origin of the Pioche Mountains.

ORIGIN OF THE PIOCHE MOUNTAINS.

The Pioche Mountains extend directly across one of the long north and south valleys of southeastern Nevada. In order to gain some idea of their relations to the surrounding country, let the reader imagine himself standing on these mountains and facing the north. Before him is Duck Valley; behind him is Meadow Valley; to the northwest is the Ely Range, and to the southwest the Highland Range. Cedar Range lies at the northeast and Mormon Range at the southeast.

Duck Valley is broad and flat. The hills at the east are low and rolling, while those at the west are slightly sharper. The valley floor is covered with a deep layer of recent wash. The whole northern section is much rounded and shows signs of long erosion.

Meadow Valley, at the south, is quite similar, except that in Tertiary times a volcanic outburst dammed its waters and converted it into a lake or dry basin, into which the intermittently flowing streams carried their loads. In the course of time the valley was filled as high as the top of the volcanic obstruction, which was then cut down, and through the outlet thus afforded the larger part of the Tertiary beds was removed. Since then the

valley has been cutting deeper and deeper. In the north it is broad and open, while at the south it gradually narrows and deepens until, in the vicinity of Caliente, it forms a typical box canyon. With the exception of this recent Tertiary deposition and subsequent erosion the topographical features bear evidence of great age.

The Ely Mountains comprise formations ranging from the Cambrian to the Carboniferous. The Highland Range is composed chiefly of Cambrian strata, although the Silurian and the Devonian are represented.

The Cedar and Mormon Ranges are formed wholly of Tertiary volcanics, which have completely covered the preëxistent formations.

The stream running from Duck Valley into Meadow Valley has cut directly through the Pioche Mountains. According to the old explanation that a mountain so affected by a stream is always younger than the stream itself, we should be forced to the conclusion that these mountains have arisen across this valley since its stream course was determined. There is every evidence to believe, however, that this is not the case, but that the mountains have been discovered by the stream. In other words, they are mountains of circumdenudation, so far as the present topography is concerned.

The evidence at hand leads us to believe that the whole country has been denuded of the higher Paleozoic formations, which even now have vestigial representatives in many parts of this region.

A correlation of the Cambrian sections in the Pioche and Highland ranges shows that fully two thousand feet of the upper beds have been removed from the Pioche Mountains. In the Highland range there are other strata aggregating two thousand five hundred feet before the Trenton horizon is reached. The Paleozoic section as a whole must have had an enormous thickness.

It has already been shown that the topography of the Pioche Mountains has been established with no apparent regard for the faults and other disturbances of the region. Indeed, the anticlinal movement and its accompanying phenomena had all been completed long before the present topography was outlined. This means, then, that the anticlinal movement and its attendant faulting occurred while the existing formations were deeply buried under others which have since been removed.

It has already been noted that the anticlinal axis and mountain axis do not coincide, except where they cross. If one imagines the fold divided into four quadrants, and so eroded that the northeast and southwest parts remain while the other two are carried away one may have in mind the general relation of the anticline to the mountains. The northwest and southeast members are now represented by a few vestigial exposures, while those at the southwest and northeast form the backbone of the mountains. It follows that while in the main it is true that the anticlinal roll has been a factor in determining the present topography, it is evident that in many ways erosion has acted absolutely regardless of it. This condition is susceptible of but one interpretation; that the anticlinal movement and its accompanying disturbances are much older than the present topographical features, and, further, that these mountains are but remnants of the great Paleozoic formations which at one time covered this entire region.

So far as known the whole of this country was raised above water level near the close of Paleozoic time; since then it has been subject to erosion. It is not at all improbable, however, that a condition of peneplanation has been reached since then, and that through rejuvenation it is now undergoing the process for the second time.

Streams traversing an uprising peneplain have little or no regard for preëxisting structural features. Upthrust and downthrust blocks are subjected to the same treatment. Anticlines are traversed as easily as horizontal beds. The resulting topography will be governed wholly by the ability of the various formations to resist the eroding influence to which they are subjected. Therefore, it is possibly true that the stream which cuts across the Pioche Mountains is older than the present topography, but it does not follow that the mountains were elevated across its course.

The Pioche Mountains, then, are the immediate result of circumdenudation; in other words the discovering processes of peneplanation.

THE HIGHLAND DISTRICT.

The Ely Mining District in which Pioche is situated forms an area six miles square, the western boundary of which lies just beyond the Point Mine. The Highland District is of equal size and adjoins it on the west. Stampede Gap, a broad open canyon, extends east and west through the central part, and separates the

Ely Mountains on the north from the Highland Mountains on the south.

There are several igneous dykes occurring here, chief among which is the western extension of the Yuba Dyke. Wherever ore has been found it is closely associated with these intrusions. At the time of the writer's visit to the region some promising prospects were being developed at various places. The Mendha mine, to which reference will be later made, is situated within this area.

The stratigraphy is almost identical with that at Pioche, except that the higher Upper Cambrian is preserved. A section of the Highland Mountains taken on the west slope is given elsewhere in this report. The limestone covers by far the greater part of the district.

About two miles to the northwest of the divide at Stampede Pass the intrusion of a granite boss has tilted the strata so that the complete series down to, and including the quartzite, is exposed. Metamorphic and dynamic action has so changed the original sedimentary condition that the section is of little stratigraphic interest. The quartzite is usually hard and vitreous; the shale is altered to a mica schist, and the limestone to marble. No traces of fossils were observed. The granite extends for several miles to the northward and forms the core of a series of hills which are but slightly subordinate in altitude to the mountain axis. It was reported to the writer that some good contact deposits of copper ore had been found.

The ridge which forms the divide at Stampede Pass reveals a number of interesting conditions. It is nearly one mile long and rather narrow with quite precipitous slopes. The crest of the ridge strikes in a north and south direction. A few hundred feet from the northern extremity of this divide the country rock, limestone, is suddenly replaced by a very large mass of iron ore, which consists of magnetite, hematite, and limonite, the two latter predominating. Farther to the south the iron slowly gives place to garnet; the transition is so gradual that a separating line or zone cannot be established. With the loss of the iron the garnet becomes almost pure and very massive, although crystals are common. From this point on iron pyrite gradually enters until at the south contact with the limestone it forms perhaps 50 per cent. of the mass. Taken as a whole this iron garnet body is about three thousand feet long by two thousand feet wide.

The iron oxides were mined at the time the smelters were in operation at Pioche; they appear to be fairly pure, but no results of analyses are at hand. Molybdenite is associated with the pyrite and garnet at the south contact; but to what extent this mineral occurs cannot be stated as no prospecting has been done for it. The entire mass is traversed in several directions by veins of almost pure quartz. An investigation as to the source of this apparently foreign material would be interesting.

In most respects this great body appears to be the results of contact metamorphism. Such large quantities of iron are not, however, necessarily associated with that process, in fact they are somewhat unusual under such circumstances. The most singular feature of all is the apparent absence of any igneous intrusion by which these conditions could have been brought about. It is true, that the Yuba Dyke passes within a thousand feet, but it is entirely too small to produce the result here shown. An examination of the country to the southwest may reveal the presence of some igneous body sufficiently large to account for the condition.

PART II. PETROGRAPHY.

THE IGNEOUS ROCKS.

So far as known all of the igneous rock of the district, with but one exception, is confined to the Yuba Dyke. The exception is a small mass of tuff apparently interbedded with the quartzite at the Eiler property about three miles northwest of Pioche. As elsewhere stated, the dyke extends from the Alps mine in the east to Stampede Pass in the west, covering a distance of about ten miles. The average width of this intrusion is probably seventy-five feet. It was apparently introduced long before the present physiographic features were outlined. In consequence of its age the material of which it is composed is now highly altered. Of the original minerals, quartz is practically the only one remaining. Specimens of the dyke brought from a depth of fifteen hundred feet at the Raymond and Ely mine show almost as much alteration as those from near the surface. The rock from the Abe Lincoln tunnel is the only exception, in that it is remarkably well preserved. It shows a number of interesting features which will be discussed in a later paragraph.

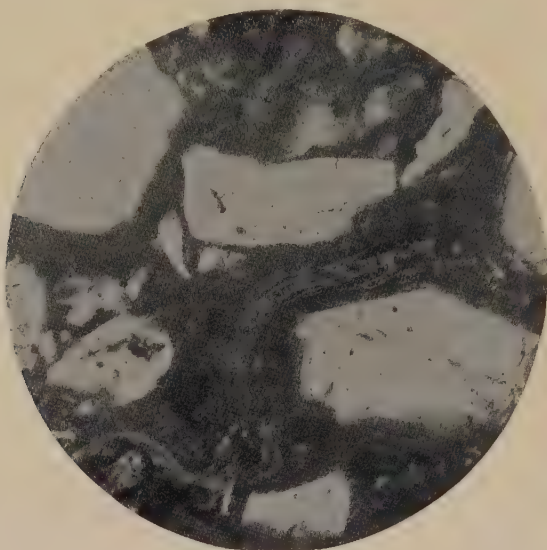


FIG. 1. Rhyolitic porphyry from Abe Lincoln mine.

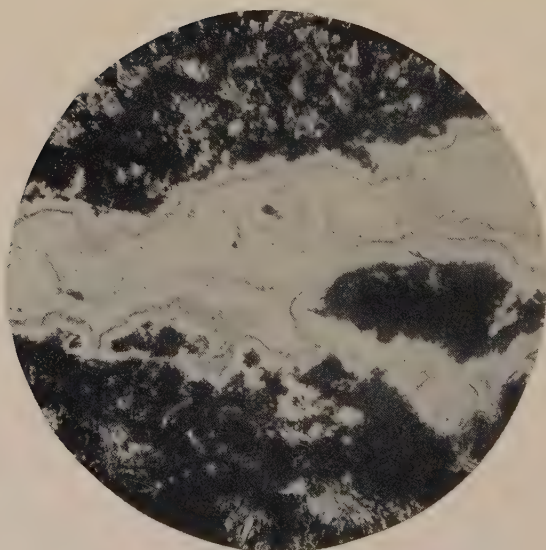


FIG. 2. Altered tuff from the Eiler property.

The igneous rock comprising the dyke in the vicinity of Pioche may be described as originally a rhyolitic porphyry composed of quartz, feldspar, mica, iron ores, and probably hornblende. Of these minerals the feldspar has practically disappeared; only vestiges of the mica and hornblende remain, but the quartz is still clear and fresh. A hand specimen looks not unlike a quartz porphyry with its typical felsitic groundmass. The rock encountered at the fifteen-hundred-foot level in the Raymond and Ely mine carries a fairly rich dissemination of minute pyrite crystals.

The igneous rock at the Abe Lincoln mine is composed of quartz, orthoclase, a little plagioclase, biotite, iron ores and a little hornblende, all of which are inclosed in a glassy groundmass showing pronounced flowage structure. The crystals are all fairly large and with but few exceptions are remarkably well preserved. They show the result of considerable resorption, which, of course, occurred at the time marked by the flowage. It appears that the original crystallization must have taken place under conditions of slow cooling, perhaps at great depth. The step toward re-fusion, indicated by the resorption and flowage, may have been due to release of pressure occasioned by the sudden advance of the dyke toward the surface. Under such conditions the upper and outer parts would normally chill rather quickly and thus form a glassy matrix enclosing the corroded crystals. It is evident that the mass had become well crystallized when the re-fusing process began, and that the second cooling was very sudden.

The tuff occurring at the Eiler property is apparently interbedded with the Lower Cambrian quartzite, and, therefore, reached the surface at some time during the period while this formation was being deposited. It was encountered in an open cut by some mining prospectors. It breaks readily, and with a hackly fracture. The hand specimen is yellow, and in that respect looks not unlike molasses candy. The fragmentary nature of the rock may be partly detected by the unaided eye. Under a lens this condition is plainly seen. A thin section reveals the fact that all of the original minerals have gone, and that the rock is now composed wholly of epidote and chalcedony. The epidote occurs massive, although minute individual crystals are not uncommon. The chalcedony forms botryoidal and mammillary aggregates along the crevices and in the cavities. It comprises perhaps seventy-five per cent. of the entire mass.

From an economic standpoint the igneous rocks of the district are very important. They appear to have been the source from which all of the ore deposits were derived. This is discussed at length in another part of this paper.

PART III. ECONOMIC GEOLOGY.

HISTORY OF THE ELY MINING DISTRICT.

Very little is known of the early history of Pioche. It appears, however, that ore was first discovered by some of General P. E. Connor's soldiers in 1862. Two years later some prospectors from Salt Lake City formed a mining district and staked off some claims, among which were the Burke and Panaca of later years. Very little work was done and the district was practically abandoned.

The Mormon village of Panaca is situated eleven miles to the south; it is said that on several occasions citizens of that community raised considerable excitement over the supposed ore bodies at Pioche. Practically nothing was done, however, until the summer of 1869 when John Ely and some other San Francisco mining men decided to prospect the region. A new district was formed, and new laws were adopted. The Burke mining claim was the first to be located. A shaft sunk upon it revealed good ore from grass roots. Excitement ran wild. Scores of claims were located in the immediate vicinity, many of which later became good producers.

Among the many misguided efforts in the early history of the camp was the building of a smelter in the winter of 1869-70, before the ores had been tested as to the proper method of treatment. The smelter proved a failure, for the reason that there was not sufficient lead in the ores to carry down the silver and gold values.

It was left to Alix Janin of White Pine to propose a treatment for the ores. He demonstrated that they would yield readily to amalgamation when salt and bluestone were added. Mills were, therefore, constructed at several points in the region as close to the mines as the water supply would permit. Mr. W. H. Raymond, an owner of one of the mills, and Mr. Ely soon became partners and incorporated the Raymond and Ely Mining Company. The company owned the Burke, Creole and Vermillion mines, which were practically the only ones operated by it in 1869-70.

The Meadow Valley Mining Company was also incorporated in the fall of 1869, and immediately took the lead in the district's production. This company owned nearly 2,500 feet along the outcrop of the great Pioche vein. Prospecting was energetically pushed, and large ore bodies were soon revealed.

The Raymond and Ely and Meadow Valley mining companies soon established themselves as the principal producers of the district. During the year 1871 the latter company still retained its position in the lead with a production of \$1,753,708, against \$1,361,628 of the former.

The Raymond and Ely Company was constantly acquiring more mining property, among which was the Panaca claim situated at the west of the Meadow Valley group. In the spring of 1871 Mr. Lightner, superintendent of the company, sunk a shaft on this property through barren shale for a distance of 100 feet, and then very luckily struck the great "bonanza" of the district.

The year 1872 opened propitiously for both companies, but subsequent development proved that the expected output of the Meadow Valley Company's mines would not be realized. It became quite generally known that the ores in the lower levels were poorer than those nearer the surface, yet through persistent development they produced over a million dollars, and a dividend of half that amount was declared.

Through the enormous production of the Panaca mine the year 1872 became the banner year of the district. The output of this mine alone was nearly four million dollars.

Up to this time all the ores from the Raymond and Ely Company's mines had been freighted by team to the mill situated eleven miles to the south at Bullionville. During the year 1872 a railroad covering this distance was constructed and put into operation.

The production of the district for 1873 was much less than that of the previous year. This was brought about largely through litigation and decrease in ore values.

In the early part of 1874 the Lightner shaft was pushed to a depth of 1,214 feet where the water level was struck. In order to develop further it became necessary to install pumping machinery. An enormous ten-inch Cornish pump was put in place, and was practically ready to begin operations at the close of the year.

In July of the same year Meadow Valley shaft No. 3 reached a depth of 1,314 feet on the incline, at which point water was encountered. Prospecting was carried on thoroughly at water level but no large bodies of ore were discovered.

The mine operators were confident that a continuation of the great bonanzas would be found immediately below the permanent water, but the pumping machinery, ponderous as it was, proved entirely inadequate. The pumps continued in operation for four months without appreciably lowering the water. Exploration could be carried only 61 feet farther than before. After several unsuccessful attempts to master the water the machinery was stopped, and operations were confined to the upper workings.

The ore extracted in 1875 was taken largely from second-grade deposits that had been overlooked while the great bonanzas were in sight. The production was much less than that of any previous year.

There was no lack of prospecting above water. Literally thousands of feet of drifts were run on the various levels, but even this extensive prospecting uncovered no ore bodies of consequence.

The workings of the twelfth level of the Lightner shaft were pushed to the west for several hundred feet along the water line, but little or nothing of value was revealed. It is asserted that later this drift was carried 2,100 feet to the west of the shaft and there penetrated the so-called "black ledge." Upon this deposit a winze is reported to have been sunk some 300 feet revealing a large body of basic ore, which consisted of argentiiferous lead and zinc sulphides.

The remaining history of the Raymond and Ely and Meadow Valley mining companies is brief. Both had money in the Bank of California, and when in 1876 it failed the last resource was gone. Operations immediately ceased. Others of the mining enterprises persisted in continuing the work, but when these two companies shut down the life of Pioche was gone.

For the last thirty years the mines have been practically idle, except for a season about 1890 when W. S. Godbe of Salt Lake City again started the wheels of the ponderous machinery at the Lightner shaft. The shaft was retimbered; the drift at water level was cleaned; and the water in the reported winze was raised. Again it was demonstrated that the pump was incapable of doing the required work, and operations were soon abandoned.

Mr. Godbe bought up many other mining properties, and for a time it appeared that the district would again become a heavy producer. A small smelter was built and proved quite efficient. Railroad connection was made with the mines at Jack Rabbit, sixteen miles distant. A second and larger smelter was soon constructed. Several mines along the Yuba Dyke were opened and profitably worked.

Mr. Godbe apparently believed in having his equipment of the very best design. Fortunes were spent in getting ready to work, instead of developing the mines on a large scale. Those who backed him financially grew tired of this policy, and when the fall came in the price of silver in 1893 all operations were suspended.

Just now the Nevada-Utah Mining Company is cleaning up around the buildings, preparatory to the reopening of some of the old workings.

THE ORE BODIES.

The ore deposits may be divided into three classes: the fissure veins, the contact deposits, and the bedded deposits. The fissure veins are by far the most important, especially from an economic standpoint. The great Raymond and Ely-Meadow Valley ore body belongs to this class, as do also the cross fissures. The contact deposits occur along the igneous dyke. The ore bodies found within this intrusion will also be considered with them. A typical example of the bedded deposit occurs at the Half Moon-Abe Lincoln property. There are also other bodies of this nature at the Mendha and the Point mines.

Each class will be discussed separately, but it may be previously stated that in general only a small part of the ore-bearing fissures are the immediate result of the original anticlinal movement. In other words, most of them were formed subsequent to that phenomenon unless, indeed, we may consider that it has not yet ceased. There is every reason to believe that the fissure veins at Pioche and the contact deposits were introduced at a comparatively recent date.

THE FISSURE VEINS.

The Raymond and Ely-Meadow Valley vein is situated on the north slope of the hill immediately south of Pioche. It strikes a few degrees north of east and dips to the south from 50 to 80 degrees, averaging very close to 70 degrees. The thickness varies from a mere seam to nine feet, the average being from two

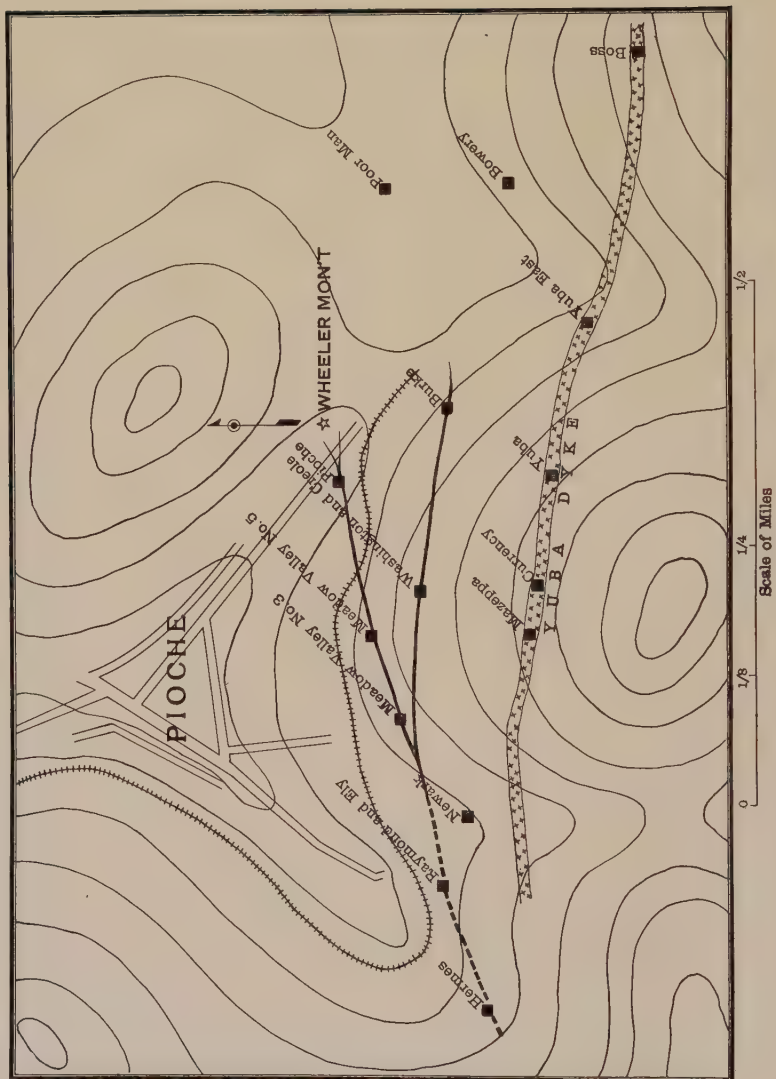
to four. It outcrops strongly in the quartzite, but when the shale and limestone formations on either side are reached it pitches down along the contact. It does not enter the limestone at the northeast, but a note in an official report states that a stringer was followed for two hundred feet into the limestone at the southwest; no values, however, were found. The vein at both extremities continues quite strong to within a short distance from the contact and then suddenly goes to pieces.

In the majority of mining camps where limestones are involved in the section the ores have shown a decided preference for them, but at Pioche this rock has been avoided at nearly every point. This apparent exception is largely due to the fact that the ore carries but little lead which is the metal showing strong affinities for limestone. The rule is not so rigid in the case of silver ores without lead, if, indeed, it holds at all.

Immediately south of the town the vein emerges from the shale and strikes across the northern slopes of Treasure Hill in a direction 75 degrees east of north. It extends but a few hundred feet and then divides. Of the branches thus formed one continues in the course of the main vein; the other strikes nearly due eastward.

In describing the location of the various mines upon this deposit in 1872 Dr. R. W. Raymond imagines his reader standing at the point of bifurcation and facing the north. He then states: "Behind him rises the mountain, before and below him clusters the town of Pioche, and beyond that the wide prospect of a vast valley, bounded by mountains far away. To the right the two divergent branches of the vein are thickly set with shafts and hoisting works. They differ in their course by about 20 degrees. To the left (west) the single vein continues, barring a break, caused by a barren cross-course of brecciated material, mischievously interjected by nature to help the lawyers. The different claims lie on the surface as follows: West of the bifurcation the Meadow Valley Co. holds three hundred and forty feet; east of the same point the same company holds one thousand five hundred and twenty feet of continuous mining ground, through the whole of which the workings of the company extend, constituting a magnificent mine.

"Next to the Meadow Valley line on the west, comes the Panaca mine of the Raymond and Ely Company covering, I believe, six hundred feet, and containing the most remarkable body of high grade ore now to be seen on the coast.



"On the east, beyond the Meadow Valley line on the south branch we have the Washington and Creole, two hundred feet, and the Burke, Creole and Vermillion mines of the Raymond and Ely Company covering I believe, about one thousand five hundred feet. On the north branch beyond the Meadow Valley line, comes the Pioche Company's ground about four hundred feet. Finally there are on both ends, and hovering about the claims enumerated, countless 'extensions' and adventures, which help to make things 'lively' in the district." The conditions described by Mr. Raymond are shown on plate VI.

The deposit is an ideal illustration of a true fissure vein. It outcropped for nearly half a mile and for two thousand feet of that distance it was mined right from the surface. The country rock was firm and stood well. Very little timbering was necessary. In consequence of this the workings are still open. One may now stand at the brink of this great chasm and see far down into the old workings, the vision being limited only by the darkness.

The vein material was quite silicious. The ores consisted largely of chlorides of silver and carbonate of lead, carrying a small amount of gold. Sulphides were occasionally seen even near the surface. The lead was generally present only in small amounts; it is assumed by Dr. Raymond that it did not exceed more than two or three per cent. The Meadow Valley Company, however, found one body containing nearly five thousand tons of almost pure lead carbonate.

By far the greater part of the production of the district has come from this vein alone. The Burke mine was the first located upon it, in fact it was the first in the district. Pay ore encountered at the surface was followed to a depth of about three hundred feet; beyond that point no valuable deposits were discovered.

The Meadow Valley Mining Company opened large and almost continuous bodies of high-grade ore throughout the entire length of their property. The vein was worked down to the twelve-hundred-foot level at which point water was encountered. The ores, however, decreased both in quantity and value beyond the eighth level.

On the Raymond and Ely property at the west the vein does not outcrop, but a shaft sunk for one hundred feet through the surface shale struck the ledge and developed the greatest bonanza of the district. The length of the ore body at the fifth level was

nearly six hundred feet; it was almost continuous from the surface and varied from one to four feet in thickness. The ore consisted of carbonate of lead and sulfides of silver; it averaged \$150 per ton.

The vein as a whole yielded its greatest values between the surface and the eighth level, below which the ores gradually became poorer. As water level was approached the oxides gave place to sulphides and large amounts of zinc also entered. At this depth the vein was generally strong and persistent, but no valuable deposits were in sight when the property was abandoned, even though prospecting had been very extensive.

A body of basic ore was encountered just below water level on the Raymond and Ely ground, but this was apparently on the dyke and will be mentioned in connection with the contact deposits.

THE CONTACT DEPOSITS.

All of the deposits considered under this heading are not strictly contact deposits, as some of them occur partly if not wholly within the igneous body. The Yuba Dyke, with which these ore bodies are associated, is situated far up the hillside south of Pioche, and in general is parallel with the Raymond and Ely-Meadow Valley fissure vein. A glance at Plate II. will make this matter clear.

Prior to and perhaps contemporaneous with the introduction of the ores the dyke suffered greatly through faulting, which in some places is confined to one contact and again to the other. Sometimes both contacts are faulted with an additional fracture or displacement within the intrusion. In the Yuba East property this fissuring has arranged itself into a parallel series extending diagonally across the dyke, and so constructed that a cross-section of this body at any point will show not less than two fissures and in most cases three.

The average thickness of the dyke is probably not more than seventy-five feet, and as a whole it is very highly fissured and faulted. This is probably the result of the somewhat sudden cooling to which so small a body would be subjected. In some parts the whole intrusion has become impregnated with silver and lead values. Indeed, assays of the rock almost invariably show the presence of these metals, and especially near ore chutes.

Most of the ore bodies are unlike true contact deposits in that they frequently penetrate the dyke and sometimes pass through it



FIG. 1. View looking north-east along the R. & E. fissure vein. The Raymond & Ely mine is in the foreground; the Meadow Valley No. 3 and No. 5, are in the distance.



FIG. 2. Meadow Valley mines. The vein was worked from the surface to a depth of 1,200 feet. The great fissure thus formed is still open.

and join with similar deposits on the opposite side. They are decidedly irregular, and occupy the fissures occasioned by the shrinkage of the intrusion. Not a single instance has been recorded of these deposits entering the adjoining quartzite.

A few fairly typical contact deposits have been found; it was from these that the greatest values were obtained. They outcropped on the surface and extended to a depth of several hundred feet.

The eastern extension of the dyke has not been found far beyond the Boss mining claim. From this point it may be traced to the westward, passing the following mines, all of which are situated upon it: Yuba East, Yuba, Currency, Mazeppa, and Williams. Among these the Yuba and the Mazeppa have been the greatest producers, both of which have been sunk to a depth of nearly thirteen hundred feet. The Williams mine contains both a contact deposit and a cross fissure.

It should also be noted that a large quantity of ore was extracted from the so-called New York ore chute. This was a contact deposit and was mined through the Raymond and Ely workings about 1890.

In this connection attention should also be called to the body of basic ore struck below the twelve-hundred-foot level in the Raymond and Ely mine. According to Mr. Earnest Godbe, this is associated with the Yuba dyke, which was encountered a few hundred feet to the south of the fissure vein. He states that a winze has been sunk upon it for three hundred feet and that the ore body is continuous for that distance. Very little water occurs in this winze, even though it is lower than the flooded workings on the fissure.

The value of the contact deposits was not recognized in the early days, and consequently but very little work was done upon them. They were developed largely by W. S. Godbe about 1890 and since then they have been idle. The Yuba East property has recently been reopened, and now some fairly good ore bodies are in sight.

THE BEDDED DEPOSITS.

So far as known the bedded veins occur in but three places, at the Mendha mine, at the Point mine, and in the vicinity of the Abe Lincoln-Half Moon mine. The first two are in limestone and the last one is in shale.

The Half Moon-Abe Lincoln ore body is in most respects a typical example of bedded deposit. It differs from others in its containing larger veins and in its stratigraphical position, but otherwise it is quite similar. The vein lies within a layer of shale some seventy-five feet in thickness, which is bounded both above and below by limestone. The thickness of the vein averages probably twelve inches. The ores are silicious. The values consist chiefly of carbonate and sulphide of lead carrying silver and a little gold. More sulphides were encountered in this class of vein than elsewhere at a similar horizon.

This property has been worked intermittently since the early seventies. The Abe Lincoln mine, which differs from the Half Moon in name alone, was being worked a year ago. The ores were milled and then subjected to cyanide process, but through some deficiency in the treatment the values were not extracted and operations were temporarily suspended.

The most striking feature of the deposits in the shale is their persistency. They may often be followed for several hundred feet with no appreciable variation in thickness. About a mile north of the Half Moon mine Messrs. Bingham and Welland have drifted on one of these for nearly five hundred feet, and have revealed a vein some ten inches thick throughout the entire distance.

This peculiar feature has led many of the miners to believe that the origin of the ore seam is similar to that of any sedimentary stratum, a view which of course cannot hold. It is not clear just why the mineralization should have been confined to a narrow zone apparently similar in composition and structure to the material both above and below. Our theories concerning ore deposition lead us to the conclusion that circulating solutions are largely if not wholly responsible for these deposits, and still it is quite impossible to believe that such solutions would influence a single layer for several hundred feet laterally, and yet not affect the material only a few inches above or below, unless for some reason this zone was particularly favorable to the circulation of the mineralizing agent. While it is freely conceded that circulation will ordinarily take place much more readily along the beds than across them, yet it is hardly possible in this case that the difference is sufficiently great to account for the facts. It appears that the deposits should be much more irregular than they are, even if the vertical passage of the solutions were confined to the pores of

the rocks, leaving out the undoubted existence of cross jointing.

At least a partial solution of this problem was suggested to the writer through a study of the ore bodies at the Mendha mine. The fissure vein at that mine has been faulted by a series of movements along the bedded planes of the limestone. Mineralization has subsequently taken place along these planes, so that they are now marked by a bedded ore deposit.

The ore bodies at the Point mine are of the same general nature, and due to the same cause. Faulting between the limestone layers accompany the anticlinal uplift, and circulating solutions later found ready passage along these planes. Both these deposits and the ones at the Mendha property are almost wholly the result of replacement.

After the unmistakable cases of faulting at the Mendha and Point mines had been studied the writer was fully convinced that the ore bodies of the Abe Lincoln type were also deposited along fracture or fault planes. They were then examined with this thought in view. The evidence was conclusive; in places simple fracturing had occurred with no apparent faulting, while in others actual thrusts had taken place.

It appears, then, that these bedded deposits mark the position of the fracture and fault planes which were formed between the beds during the anticlinal movement. Circulating solutions encountered very little resistance along these planes, and, therefore, formed thin deposits extending over large areas.

These ore bodies illustrate the stages of replacement in the simplest possible manner. The central part of the vein is fully mineralized, while on either side every point in the process is well shown. The accompanying photograph of a piece of ore taken from the Abe Lincoln mine still shows the shaly structure with remarkable clearness. (See Plate VIII., Fig. 1.)

The cause of this fracturing and faulting is an interesting subject. The Pioche anticline is composed of a core of quartzite overlain by shale and that in turn by limestone, which in a few places is interstratified with bands of shale. Some of the phenomena accompanying anticlinal movement may be illustrated by folding a pack of cards. It will be observed that each card slips on the adjoining one, and, further, that each one *rides up* on the one next lower. Two points are worthy of emphasis; first, that the

movements all occur along planes of weakness, and second, that these movements are all of the *reversed* order.

The writer is not prepared to assert that all such faulting will be of this class. A breaking down of the arch during the early stages of an uplift might render the conditions quite different, but in every case examined where movements were actually in evidence not one was of the normal type.

Now, then, in the case of the Pioche anticline the fracturing and slipping would occur along the planes of greatest weakness. Both the quartzite and the limestone are compact and massive, while the shale is very easily broken along its bedding. There appears to be no doubt that during the process of folding that the shale was thus fractured.

While it appears that the fissures now marked by the bedded deposits were formed in the early stages of the anticlinal movement and before the arch gave way, yet it does not follow that the introduction of the ore immediately succeeded. It is true, however, that the ore bodies show evidence of considerable age. They were involved in the general faulting which occurred long before the present topography was outlined. The age of the ore bodies is discussed in another part of this paper.

AGE OF THE ORE BODIES.

Under this heading the longitudinal and transverse fissure veins will be considered together; the bedded and the contact deposits separately.

The Fissure Veins.—In the vicinity of Pioche the quartzite core has been thrust up between the flanking shale and limestone, and is now separated from them on both sides by a well-marked fault plane. This displacement occurred subsequent to the anticlinal movement. Indeed, its completion marks the last stage of that process, and yet, as shown elsewhere, there is reason to believe that the faulting is so old that the present topographic features were outlined quite independently of it.

The relative age of the ore bodies must be determined by comparison with the principal faulting.

The fact that the ore deposits are confined almost exclusively to the quartzite has lead to the belief that they were formed prior to the deposition of the superjacent shales. This cannot be the case, as their attenuated extremities have been traced into this formation

and also into the still higher limestone. And, further, there is complete proof of continuous deposition from the quartzite into the upper members.

At one time it was thought that the lateral extension of the ore bodies was marked by the two parallel faults which separate the shale and limestone from the quartzite. If this were true it would follow that the ore bodies are older than the movement which elevated the quartzite block. This, however, is not the case for the Raymond and Ely vein has been followed across the south fault into the quartzite normally subjacent to the shale.

Whether or not the vein was displaced by the fault cannot be specifically stated, as the mine workings are inaccessible and the desired data cannot be obtained from the records. The vein beyond the point of intersection does not outcrop, but the shafts sunk upon it are situated in the exact direction of its strike on the opposite side of the fault, a fact which indicates that the vein was not affected by the faulting movement. If the deposit had existed before this displacement occurred, it would have been heaved several hundred feet. It follows then that the Raymond and Ely-Meadow Valley fissure vein is younger than the movement which resulted in elevating the quartzite to its present position.

It is true that this vein has been displaced by one or more cross faults; it may also be the case that it has been fractured or perhaps slightly thrown by the northwest-southeast fault to which reference has just been made. This would not militate against the conclusion concerning the relative age of the ore body. A slight displacement of the vein could be explained by reason of the fact that old fault blocks frequently readjust themselves, even long after the principal movements have ceased. Nothing but a considerable heave could possibly be the result of the entire movement as the blocks were thrown fully one thousand feet on a plane which dipped sixty degrees.

The Bedded Veins. — These deposits show evidence of much greater age than the veins in the vicinity of Pioche. The ore body at the Half Moon mine has been thrown by one of the principal longitudinal faults which probably had its beginning back in the middle period of the anticlinal movements. The vein is also displaced by the cross fault that threw the Mt. Ely block down.

According to evidence elsewhere stated it appears that these deposits mark the positions of fault planes, which were formed

along the bedding as the folding of the anticline progressed. And from the above it is seen that they were displaced by the longitudinal faults. We may, therefore, feel reasonably sure that they were introduced soon after the folding process began.

The bedded veins at the Mendha mine occur along fault planes which were formed while the country rock was being folded. Concerning the age of this movement there is much uncertainty, but there is no evidence to indicate that it is recent.

The associated Mendha fissure vein was displaced by these faults, and is, therefore, older than the faulting. Nothing more definite can be stated.

The Contact Deposits.—The contact deposits in the vicinity of Pioche are found in association with the Yuba dyke. They occur within this igneous body as well as along the side of it, and were formed subsequent to its introduction. Moreover, the dyke cuts directly across one of the two principal faults, thus proving that its intrusion and the deposition of the associated ore bodies occurred since the upthrusting of the quartzite formation in which they are situated.

Therefore, the age of the contact deposits is the same as that of the neighboring fissure vein. The events discussed in the foregoing paragraphs appear to have occurred in the following order:

1. The anticlinal movement and the attendant shearing along the bedding planes of the shale.
2. The deposition of the bedded ore deposits.
3. The breaking down of the anticlinal fold.
4. The intrusion of the Yuba dyke.
5. The deposition of the fissure veins and the contact deposits.
6. The minor cross fissuring.

The anticlinal movement probably took place during the general elevation of the region at the close of Paleozoic time. No higher strata, however, than the Upper Cambrian are now found in the anticline, the upper formations having been carried away by erosion. The Eocene deposits at the south of the Pioche Mountains have not been disturbed by any of these processes. It can only be stated, then, that these phenomena occurred between the close of Paleozoic time and the beginning of Eocene time.

RELATION OF THE ORE BODIES TO THE IGNEOUS INTRUSIONS.

The early mine operators appear to have attached very little or no importance to the presence of the Yuba dyke, if, indeed, they

were aware of its existence. No allusion whatever is made to it in the early reports of the various companies. Prospecting was carried on apparently without even a general conception of the source of the ores; in fact, hundreds of holes were sunk where there were no "indications" whatever. Some little work was done on the dyke itself in the early days, and some very good deposits were uncovered, but the genetic value of this igneous intrusion was not realized until many years later. To-day the miner knows full well that it is quite unprofitable to prospect at any great distance from it.

It has already been noted that the mines at Pioche are grouped along the side of the Yuba dyke, none of them being situated more than one thousand feet from it, and many of them very much closer.

The great Raymond and Ely-Meadow Valley vein runs nearly parallel with intrusion; the two converge slightly toward the west, and, strange as it may appear, the nearer they approach each other the more valuable are the ores. This increase of values toward the intrusion is shown in the fact that the production of the Pioche mine, away out on the extremities of the vein, was only fair, while Meadow Valley No. 5, which was still closer to the dyke, was much better. Meadow Valley No. 3 was still richer, and the Panaca claim of the Raymond and Ely Company was by far the greatest producer of the district, and in its southwestern extension it came almost into contact with the dyke.

Another noteworthy feature is that the cross fissures are unprofitable except near their intersection with the dyke. A typical example of this is the Mike Williams property, situated immediately south of Pioche. This vein cuts the dyke at an angle of, say, 45 degrees. It has been very profitably worked near the intrusion, but away from it in both directions the values suddenly disappeared.

The relation of the fissure veins to the dyke is also shown in the fact that they approach each other in depth. The dyke dips to the south at an angle of 80 degrees; the vein dips in the same direction at an angle of 70 degrees. This means that if the dips remain constant these bodies will unite in depth, possibly somewhere between fifteen hundred and two thousand feet. See Fig. 8.

At the twelve-hundred-foot level in the Raymond and Ely workings a drift was run from the vein to the dyke, which at this depth was very much closer to the vein than at the surface.

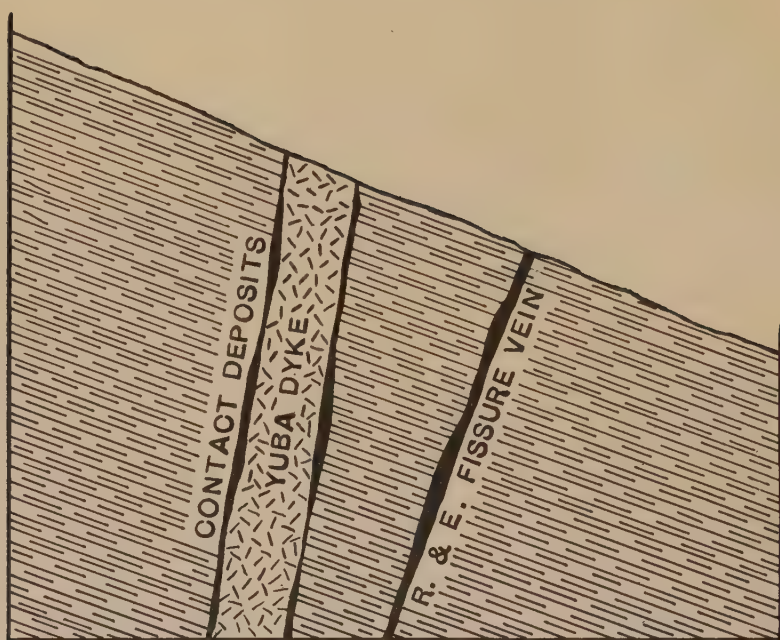


FIG. 8. North and south section across the Yuba dyke and the R. & E. fissure vein.
(Showing that the two approach each other in depth.)

The fact should not be lost sight of that the deposits on the dyke itself have added largely to the production of the district. The ores had every evidence of coming from the same source as those in the fissure veins. They were high in silver and carried some lead and gold. It is true that the lead values were proportionately a little higher than elsewhere and that there were more sulphides, but this is without doubt due to the fact that the intrusion is more basic as shown by the disseminated crystals of iron pyrite.

The western extension of the dyke in the Stampede Gap region has never been prospected, but surface indications are good. There is scarcely a distance of one hundred feet along its course that does not show mineral outcrop. Two shafts now being sunk in this section have very good showings.

The fissure vein at the Mendha property is also very closely associated with an igneous intrusion in fact the two apparently intersect.

The underground workings of the Alps mine reveal a close relationship of the ores with the dyke. The vein strikes east and west, outcrops on the surface, and dips slightly to the south. It has been worked through drifts run from a shaft at the north. At the three-hundred-foot level a seam of silicious shale was encountered and the ore body was lost. A drift run through this member entered an igneous dyke immediately below the vein. A continuation

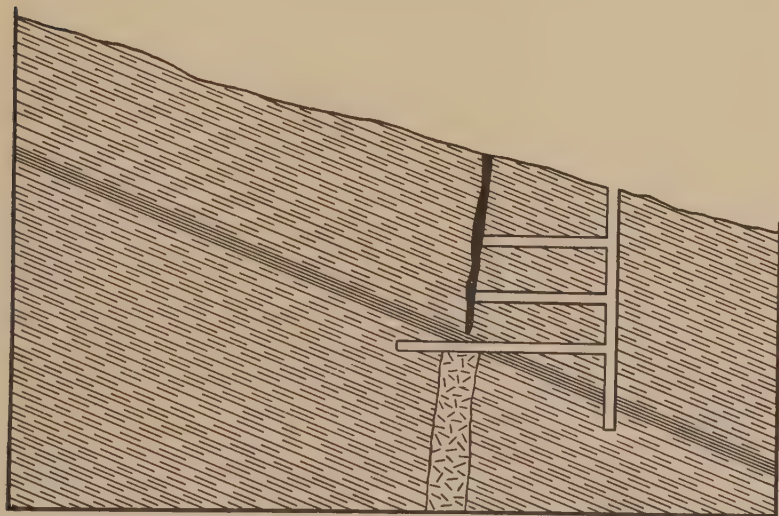


FIG. 9. Section at the Alps mine showing the relation of the ore body to the igneous intrusion.

of the ore deposit has never been found below this point, in fact little or no search for it has ever been made. The relationship of these various features is shown in the accompanying figure. The mine is situated in the direct line of the strike of the Yuba dyke at Pioche, but there are no igneous outcrops within half a mile of this property.

It is thought by one of the old mine operators that a fault has occurred along the bedding of the shale, and thus by chance the dyke and vein have been brought opposite each other. According to his view this has occurred since the deposition of the ore. A careful search was made for evidence of movement, but none was found. The vein is very much shattered and begins to pinch out at a considerable distance above this point. It appears that the

present relation of the vein to the dyke has not been changed since the introduction of the ore.

PROCESSES OF MINING.

The principal mining of the district has been confined to the quartzite, which as a rule is strong and massive. Some shattered zones were encountered, but in the main the walls were sufficiently strong to stand without support. The veins within the quartzite were all nearly vertical, and none of them were very wide. Timbering was quite unknown. The mines were all dry, and, therefore, not subject to the destroying action of percolating waters. The writer entered some of the old workings of thirty years ago, and found the walls still standing and generally well preserved. Very little crumbling has taken place even in that time.

The method of working the vertical veins was simple. The shaft was kept ahead of the drifts, which were run at convenient levels and the ore stoped down in the usual way. Many of the workings reached directly to the surface, and in these the men had to be protected from falling material, by means of planks placed upon cross stulls above them. Otherwise, except in the shafts, timbers were seldom used.

The contact deposits were mined in nearly the same manner. Timbers were not generally used, although they were required more frequently in the dyke material than elsewhere.

The bedded veins were thin, and it therefore became necessary to take out some of the wall rock with the ore. They were mined much the same way as coal seams; pillars were left at proper intervals for support. It is really surprising to see the great areas of unsupported roof that have stood for the past thirty years.

As a whole the matter of mining was a rather simple one. The ore bodies were not over large; the wall rock was firm and until the lower levels were reached there was no water.

The accompanying table gives a fair idea of the cost of mining. While at first sight the figures may appear high, yet it should be remembered that the work was done under very unfavorable conditions. The railroads were nearly three hundred miles away; freight rates on supplies were excessive and labor could almost demand its own price.

The low rate of extraction of the Raymond and Ely Company in 1872 marks the time when the great bonanza was being mined.

The highest cost for both companies occurred in 1874. This was brought about by the protracted litigation and its accompanying evils. The mines were fully patrolled by men commanding \$20 per day.

COST PER TON OF MINING.

Year.	Company.	Extracting.	Prospecting and Dead Work.	Incidentals.	Total.
1871	Meadow Valley.	\$14.20	\$5.71	\$4.59	\$24.50
1872	" "				38.55
1872	Raymond & Ely.				14.45
1873	" "	13.67	12.19	5.97	31.83
1874	" "	23.06	50.06	6.13	79.25
1874	Meadow Valley.	22.19	48.87		71.06
1875	Raymond & Ely.	14.78	20.18	10.14	45.10

During the year 1875 the rate again dropped, but this is rather deceptive as by far the greatest amount of dead work was done during that period. Nearly two hundred and seventy thousand dollars were spent upon these operations alone. The production in tons was very high but came largely from bodies of low grade ore which had been previously blocked out. The average yield of these ores was \$52.36 per ton against a cost of mining of \$45.10. Scarcely more than sixty per cent. of the values were recovered in the mill.

PROCESS OF REDUCTION.

The ores consisted chiefly of chloride of silver and carbonate of lead with some sulphides of these metals. They usually carried about one dollar in gold to twenty dollars in silver. There were two classes, one described as "free" and the other as "base." The values of the first were chiefly in silver, of which approximately 80 per cent. was the chloride. The base ore carried both lead and silver in varying proportions. In this the silver values were about 45 per cent. chloride and the rest probably sulphide and oxide. By far the greater part of the ores of the district belonged to the class described as base.

During the winter of 1869-1870 a smelter was built for their treatment, but it proved a failure because of the small percentage of lead present.

It was then learned that the "free" ores would yield their values readily by the process of pan amalgamation, but from the "base" type not more than 50 per cent. could be recovered by

this method. Alix Janin, of White Pine, was finally successful in demonstrating that the latter would amalgamate freely when salt and copper sulphate were used with the charge in the pan before the introduction of the mercury.

Early in 1870 the Meadow Valley Mining Company erected a twenty-stamp mill at Dry Valley, ten miles to the east of Pioche, where there was a good supply of water. Later ten more stamps were added. Salt and copper sulphate were used in this mill with very satisfactory results. About 80 per cent. of the values were extracted when these chemicals were used compared with 60 per cent. without them.

The lead was separated from the bullion by passing the mercury and amalgam through a sack suspended in boiling water. The lead amalgam being liquid at this temperature passed through the sack with the mercury, leaving the amalgamated silver behind. These products were in turn retorted in the usual way, resulting in two grades of bullion, one about 750 fine and the other about 100 fine.

In the fall of 1869 W. H. Raymond constructed a small five-stamp mill at Bullionville, near Panaca, and some eleven miles to the south of Pioche. When he first began operations he treated the base ores without chemicals. The result was that he extracted less than forty per cent. of the values. Later the character of the ores changed and the results were much more satisfactory. Still later salt and blue stone were used as at Dry Valley.

Bullionville soon became the milling center of the district. The Raymond and Ely Mining Company had at least two mills here; one a twenty-stamp wet crusher and the other a thirty-stamp dry crusher, which was later converted into a wet crusher. W. H. Raymond put in another mill of ten stamps, and the American Flag Mining Company one of twenty stamps. Besides these there were some others of varying degrees of merit and success.

It was necessary to locate the mills at Bullionville because of the aridity of the country in the immediate vicinity of the mines. The expense of freighting the ores from mine to mill ate largely into the profits. A project for connecting these places by rail was completed some time in the latter part of 1872 or in the early part of 1873. Engines, cars, rails, and in fact all equipment had to be freighted by team from distant points in Utah, but this great expense was soon returned in the saving of freight rates.

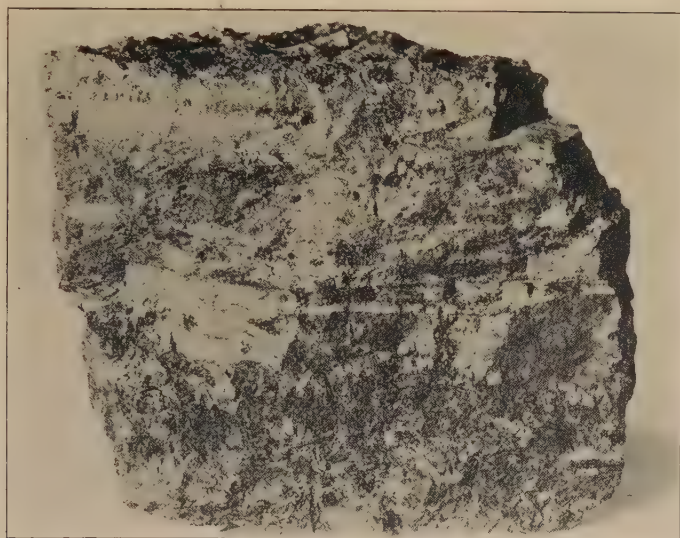


FIG. 1. Ore from the Abe Lincoln mine. (Showing various degrees of replacement.)



FIG. 2. Practically all that remains of Bullionville.

Bullionville in the early seventies was one of the busiest towns in the far West. To-day its site is marked by a single smoke stack, some dumps, and a few crumbling walls.

Since it was abandoned a large part of the old mill dumps have been reworked. Just how much was recovered from them can hardly be even approximated, but old miners claim that it approached a million dollars.

It now remains for some one to sample the portion of the dumps that have not been reworked and to install a plant suitable for the extraction of the remaining values. Such an enterprise should be followed by profitable and quick returns.

PRODUCTION OF THE ELY MINING DISTRICT.

The accompanying statistical tables show in a general way the commercial importance of the district during its period of production. They are taken from the reports of the United States Commissioner of Mining Statistics. It is hardly possible that the data here given represent the exact conditions, but none better are available. A few discrepancies are apparent; for instance, Table No. 1 shows no assessment against the Meadow Valley Company for the year 1875, while No. 2 shows one of \$30,000 as late as December of that year. The latter also has an item of \$1,290,000 as total assessment against \$210,000 in the former. It is probable that the larger amount more nearly approaches the truth, as enormous sums are known to have been levied during this the last year of the company's existence.

At first thought it may appear that all of the mining enterprises were failures with the exception of the Raymond and Ely. While this appears to be the case, yet it is misleading. Enormous bodies of high-grade ore were encountered in several of the mines; if the present facilities for mining and reduction had been available the outcome would have been far different. The failures, therefore, ought not to be attributed wholly to the paucity of ore bodies, but rather to the conditions under which they were worked. It is true that many fortunes were spent in barren ground, but the enormous production of such mines as the Raymond and Ely and the Meadow Valley places them among the foremost silver producers of the West.

TABLE I.

Year.	Company.	Bullion Receipts.	Dividends.	Assessments.
1870	Meadow Valley	\$644,719		\$210,000
1871	Meadow Valley	1,753,708	\$330,000.	
	Pioche	203,537	20,000	20,000
	Raymond and Ely	1,361,628	615,000	
	Washington and Creole			15,000
	Others			7,500
1872	Alps			37,500
	Bowery	36,485		52,500
	Hermes			30,000
	Huhn and Hunt	13,122		82,500
	Kentucky			15,000
	Louise			15,000
	Meadow Valley	1,303,537	690,000	
	Newark			40,000
	Page and Panaca			40,000
	Pioche	232,417	40,000	20,000
	Pioche West Extension			19,250
	Raymond and Ely	3,693,936	2,070,000	
	Silver Peak			15,000
	Washington and Creole	84,500		67,500
	Others			166,000
1873	Amador Tunnel	48,560		30,000
	Alps	28,177		105,000
	Bowery	4,000		30,000
	Chief of the Hill	36,814		45,000
	Hermes			60,000
	Huhn and Hunt			112,500
	Kentucky			75,000
	Newark	128,528		73,600
	Meadow Valley	738,646	240,000	
	Page and Panaca			40,000
	Pioche	72,190		70,000
	Pioche Phoenix			40,000
	Pioche West Extension			17,500
	Raymond and Ely	2,339,364	390,000	
	Silver Peak			37,500
	Washington and Creole	66,687		60,000
	Others	259,064		485,800
1874	Meadow Valley	471,958		
	Raymond and Ely	673,051		180,000
	Others	756,205		
1875	Meadow Valley	82,168		
	Raymond and Ely	738,305		330,000
	Others	229,698		

TABLE II.
TABULAR STATEMENT OF ASSESSMENTS AND DIVIDENDS, FROM THE DAILY STOCK REPORT ASSESSMENT-LIST, SAN FRANCISCO,
JANUARY 17, 1876.

Companies.	Number of Assessments.	Number of Shares in Mine.	Last Assessment Leveled.	Amount per Share.	Number of Dividends.	Last Dividend.	Amount per Share.	Total Amount of Assessments Leveled.	Total Amount of Dividends Leveled.	Amount of Assessment per Share.	Amount of Dividend per Share.
American Flag.....	7	40,000	Mar. 26, 1875	\$0.50				\$260,000		\$6.50	
Alps.....	8	30,000	Feb. 10, 1875	25				105,000		3.50	
Bowery.....	6	30,000	Dec. 15, 1874	20				94,000		3.15	
Chapman.....	4	30,000	July 28, 1873	25				37,500		1.25	
Chief of the Hill.....	6	30,000	Mar. 26, 1875	25				75,000		2.50	
Condor ..	4	25,000	July 9, 1875	50				50,000		2.00	
Huhn and Hunt.....	11	30,000	May 7, 1875	50				294,000		7.55	
Ingomar.....	7	40,000	May 4, 1874	25				70,000	\$50,000	1.75	
Louise.....	3	30,000	Sept. 15, 1872	50				21,000		70	
Mendow Valley.....	10	60,000	Dec. 28, 1875	50	17	June 16, 1873	\$1.00	1,290,000	1,200,000	21.50	\$20.00
Newark.....	12	32,000	Sept. 14, 1875	50				304,600		9.55	
Page and Panaca.....	8	40,000	Oct. 6, 1874	75				190,000		4.75	
Phoenix.....	14	50,000	Apr. 21, 1874	50				337,500		6.75	
Pioche.....	11	20,000	Dec. 1, 1875	50	3	Aug. 5, 1872	1.00	230,000		11.50	3.00
Pioche West Extension.....	8	35,000	July 12, 1875	2.00				171,000		4.90	
Portland.....	5	30,000	Aug. 21, 1874	25				71,000		2.36	
Raymond and Ely.....	5	30,000	Nov. 5, 1875	3.00	23	Sept. 10, 1873	3.00	510,000	3,075,000	17.00	102.50
Silver Peak.....	6	30,000	Mar. 29, 1875	50				105,000		3.50	
Silver West Consolidated.....	5	50,000	Dec. 7, 1875	10				42,500		85	
Spring Mountain Tunnel.....	9	20,000	May 22, 1874	10				33,000		7.35	
Washington and Creole.....	15	30,000	Sept. 27, 1875	75				315,000		10.50	
Watson.....	1	30,000	Nov. 16, 1874	1.00				30,000		1.00	

